GROUND-WATER HYDROLOGY OF EMIGRATION CANYON, SALT LAKE COUNTY, UTAH

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by

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ABSTRACT

Emigration Canyon is situated in the portion of the Wasatch Mountains that are in the eastern part of Salt Lake County in north-central Utah. A significant amount of ground-water development has taken place in the canyon in recent years to satisfy domestic water needs. This hydrologic investigation was undertaken to learn more about the ground-water aquifers in the canyon and their interrelationship so that the effects of past and future water development can be better understood.

The area under study comprises about 29 square miles in the Rocky Mountain physiographic province and ranges in altitude from 4,870 feet to 8,954 feet. The rocks in the canyon have been folded into the Emigration Canyon syncline. The axis of the syncline is near to the stream channel and roughly parallel to it. The syncline plunges to the northeast, which is opposite to the direction of flow of Emigration Creek.

More than half of the nearly 120 drilled wells in the canyon divert water from bedrock formations; others divert water from the

alluvial, valley-fill material overlying the bedrock. The bedrock aquifers in the canyon are almost entirely in the Twin Creek Limestone, the Preuss Sandstone, and the Kelvin Formation.

For this ground-water study, the area is referred to as the Emigration Canyon district of Salt Lake County and divided into four sub-districts--the Twin Creek, Preuss, Kelvin, and the Pinecrest. There are about 37 drilled wells in the Twin Creek sub-district, 12 in the Preuss sub-district, 65 in the Kelvin sub-district, and 4 in the Pinecrest sub-district. The water in the aquifers is under artesian pressures, and the pressures fluctuate annually as does the stream flow. The wells generally produce only a few gallons per minute, and their specific capacities are low.

The rights to divert water from the stream date back as early as 1847, but most of the well rights have been established within the last 20 years. The majority of the estimated 660 persons that live in the canyon on a full- or part-time basis depend on drilled wells for their water supply.

Over the past 65 years the stream flow of Emigration Creek has averaged about 4,350 acre-feet of water annually and has ranged from 13,500 acre-feet to 234 acre-feet. A thick alluvial cover over most of the canyon absorbs a large amount of the 20 to 35 inches of annual precipitation and influences the total annual stream flow. A seepage run, which was conducted in the late summer of 1965, indicates that some reaches of the stream are effluent, while other reaches are influent.

The chemical quality of the stream and all but two of the wells sampled is of a calcium bicarbonate type. The water is very hard, but it is suitable for culinary use. Two wells sampled produce waters that are very high in total dissolved solids and are unfit for culinary use. The stream is highly contaminated with coliform bacteria. Coliform bacterial contamination was found in the shallow ground water, but tests indicate that deeper sources are probably uncontaminated. During the period of study, stream temperatures varied almost 30 degrees, while temperatures of water from individual wells varied only 3 or 4 degrees and remained near the average annual air temperature of the canyon.

The annual ground-water pumpage is about 100 acre-feet of water, which is only about one-fortieth of the average annual flow of the stream. It is unlikely that present ground-water development has influenced surface- or ground-water rights, and additional drilling of small culinary wells could probably be allowed. Large wells or additional surface-water development could influence already established surface- and ground-water rights in both quantity and quality.

INTRODUCTION

Purpose and Scope

This investigation of the ground-water hydrology of Emigration Canyon was undertaken to determine the status of present ground-water development, to determine the nature and extent of the ground-water aquifers and their interrelationships, and to estimate the effects that past development had and future development will have on existing surface and subsurface water rights.

State and local officials who administer the water, as well as the water users in the area, can proceed with a more intelligent and planned development if the hydrology of the area is better understood. The State Engineer's Office is continually receiving new applications for permission to drill additional wells in Emigration Canyon. Many of these applications are for single-home use, but others are for multiple-unit dwellings, commercial developments, children's camps, and even small subdivisions. Before action for the approval or rejection of these applications can be taken, the State Engineer's Office must assess the possible effects that these proposed developments may have on already established water rights.

Most of the efforts of the writer were directed toward gathering information about the quantity, quality, and occurrence of water in the canyon. Only a small amount of the geological information that appears in this report is a result of original work by the author, and most of it is from previous works. When the interpretation of the hydrology appeared to require additional, detailed geologic data, efforts were made to obtain the required information in the field.

Location of Area

Emigration Canyon is in north-central Utah (fig. 1) and is located in the Wasatch Mountains in the eastern part of Salt Lake County. The canyon is in the Rocky Mountain physiographic province and drains westward into Jordan Valley and the Basin and Range physiographic province. Emigration Canyon is bounded on the east, north, and south by high topographic divides. The western boundary of the area is about one-fourth of a mile west of the mouth of Emigration Canyon at the stream gage operated by the U. S. Geological Survey and Salt Lake City. The drainage area above the stream gage totals approximately 29 square miles.

Previous Investigations and Source of Information

This is the first investigation made of the ground-water hydrology of Emigration Canyon. Several hydrologic investigations have been made of the Jordan Valley immediately west of the study area, but to the writer's knowledge, only a few isolated hydrologic observations were made in the canyon prior to the beginning of this investigation.

Water-flow measurements of Emigration Creek and Emigration Tunnel Springs have been made by Salt Lake City for many years; these measurements are used in this report. Bacterial and chemical analyses of water from the canyon were provided by the Salt Lake County Board of

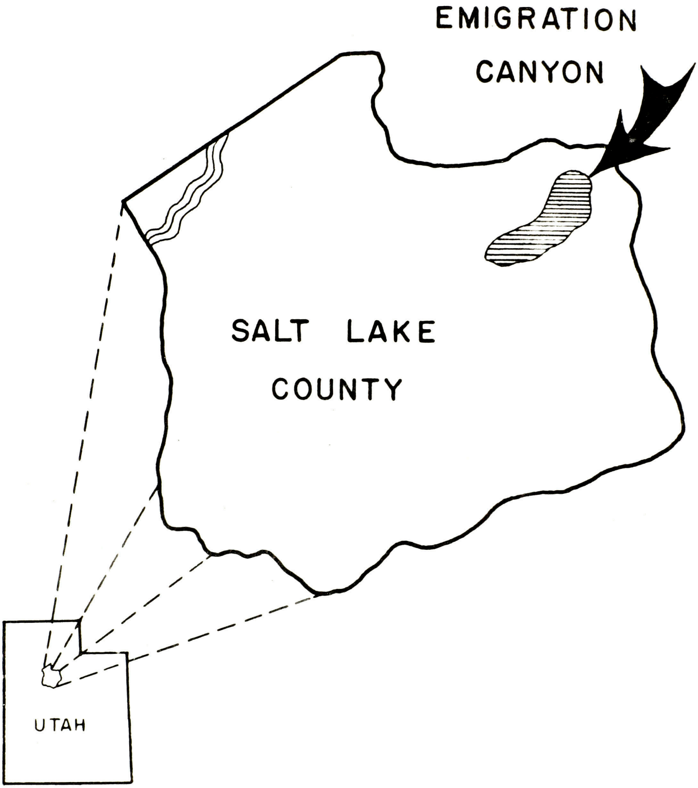


Figure 1.--Index map of Utah and Salt Lake County showing the location of Emigration Canyon.

Health. Additional chemical analyses were made by the U. S. Geological Survey in cooperation with the State Engineer's Office. The U. S. Geological Survey also provided geophysical logs of a few wells in the canyon and the results from a seepage run of the stream that was conducted in the summer of 1965.

Information concerning the water rights in Emigration Canyon and the well drillers' reports on wells in the canyon were obtained from the files of the Utah State Engineer's Office. Some of the sections in the report are heavily dependent on the information as recorded and supplied by the well drillers. Additional information was obtained in conversations with residents of the area and with the individual well drillers.

There are several geologic reports which include the study area. Two reports which were especially useful are Bull. 69 of the Utah Geological and Mineralogical Survey entitled, "Geology of Salt Lake County," and Guidebook No. 18 of the Utah Geological Society entitled, "The Wasatch Fault Zone in North Central Utah."

Well-Numbering System

The well-numbering system in this report indicates the location of a well to within a 10-acre tract in a given section. The system is used by the Utah State Engineer's Office and was devised cooperatively by the State Engineer's Office and G. H. Taylor of the U. S. Geological Survey about 1935. In this report, the locations of springs and sampling points along the stream are also designated by this system.

A sample well number within Emigration Canyon is (A-1-2)32dcd-2. The capital letter identifies the four quadrants of the State as it is divided by the Salt Lake base and meridian--A, northeast quadrant; B, northwest quadrant; C, southwest quadrant; D, southeast quadrant. The first number following the capital letter is the number of the township, and the second number designates the range. The quadrant, township, and range designations are all included within the parentheses. The number following the parentheses is a section within the township. The three lowercase letters following the section number are, respectively, the designations for the quarter section (usually 160 acres), the quarter of the quarter section (usually 40 acres), and the quarter of the quarter of the quarter section (usually 10 acres). These letters represent the various quadrants of their respective subdivisions. Each quadrant is assigned a letter--a, northeast quadrant; b, northwest quadrant; c, southwest quadrant; d, southeast quadrant. The number following the letters indicates the number of the well within the 10-acre tract as assigned by the State Engineer's Office. The prior-given well number, (A-1-2)32dcd-2, is the second well in the SE¼SW¼SE¼ sec. 32, T. 1 N., R. 2 E. An example of another well in Emigration Canyon is (D-1-1)1add-1. This is the first well in the SE¼SE¼NE¼ sec. 1, T. 1 S., R. 1 E.

GENERAL GEOGRAPHY

Topography and Drainage

The area of study is a stream-cut canyon that has been eroded by Emigration Creek. The topography of the canyon shows no evidence of being modified by glacial action, and only a small section of the canyon is at an elevation below the maximum level of Lake Bonneville. Little evidence remains today in the section of the canyon that was inundated by Lake Bonneville to indicate the existence of the lake. The stream flows to the west in a direction opposite to the dip of the geologic formations, and the topography of the canyon is perhaps as gentle as any found on the west slope of the Wasatch Mountains.

The relatively thick mantle of unconsolidated material is present almost everywhere in the canyon. Because of this thick mantle, bedrock outcrops are widely scattered.

The relief in the area of study is almost 4,100 feet. Lookout Peak with an altitude of 8,954 feet is the highest peak on the drainage divide of Emigration Canyon; the stream gage near Hogle Zoo is at an altitude of 4,870 feet and is the lowest point within the study area.

Climate

The "B" or dry climate is the major climatic group represented in Utah (Trewartha, 1937). In the dry climates, evaporation has the potential of exceeding precipitation. In Utah this climate is more precisely identified as a steppe or semiarid type (BSk). The small amount of precipitation in Utah is an expression of the State's continental position, the Pacific high pressure system, and the rain shadow of the Sierra-Cascade Mountains.

About one-third of the State, however, is classified as a highland or humid climate. As a result of increased orographic rainfall and lower temperatures, associated with the mountains, precipitation will exceed evaporation. Some climatologists would prefer to identify the climate of the upland area as humid continental. R. C. Burnham (1950) in an unpublished master's thesis entitled, "The Climates of Utah," described Emigration Canyon as having a humid, microthermal climate with cool summers. Regardless of the climatic terminology, the mountainous area of the State, including the area of Emigration Canyon, is characterized by a surplus of moisture over evaporation.

The Emigration Canyon area has four distinct seasons. Summer temperatures are moderate with daytime readings within the canyon seldom over 90^{o} and with evening temperatures 20 to 30 degrees lower than the daytime maximums. Winter temperatures are not extreme, and below zero readings are not frequent. However, for most of the winter season there is a snow cover, and Emigration Creek is often covered with ice.

Within the canyon there are many microclimates; but in general, average annual precipitation increases with altitude, and average annual temperature decreases. The average increase of precipitation with altitude on the Wasatch front is about 1 inch annually for each 160 foot rise. It is estimated that the lower elevations of the canyon receive about 20 inches of precipitation annually, while the higher elevations receive 35 inches or more.

There is no U. S. Weather Bureau observation station within the canyon; however, there is one in Parleys Canyon within 2 miles of the area of study. This station is at the Mountain Dell Dam at an altitude of 5,500 feet. Temperature and precipitation at a similar elevation in Emigration Canyon should be quite comparable. The floor of Emigration Canyon is near this elevation in the central part of the study area. The Mountain Dell station has an average annual precipitation of 21.91 inches and an average annual temperature of about 48 degrees (fig. 2).

Winter and early spring are the seasons of heaviest precipitation in Emigration Canyon. However, runoff is delayed because much of this precipitation is in the form of snow, and the peak of runoff discharge is postponed until warmer temperatures melt the snow. Water needs exceed precipitation during the late summer and early autumn months.

The vegetation varies greatly from place to place because of the many microclimates that result from variations in slope, soil, exposure, temperature, precipitation, and elevation. On the slopes sagebrush, scrub oak, big tooth maple, mountain mahogany, and grasses are common. Along the stream channel, the common vegetation includes cottonwoods, river birch, chokecherry, and dogwood. At the upper elevations, aspen and spruce-fir growth are common.

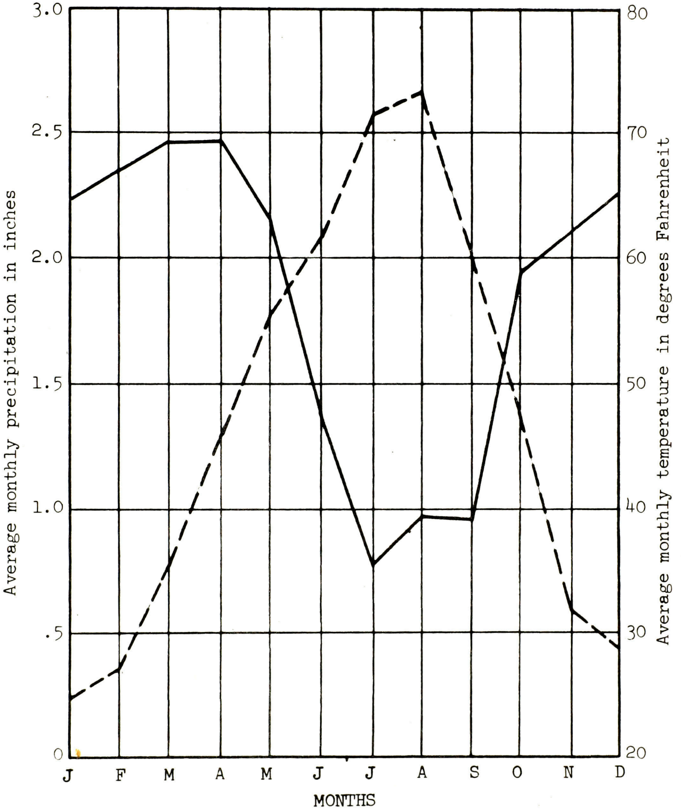


Figure 2.--Chart showing the average monthly temperatures (dashed line) and the average monthly precipitations (solid line) at the Mountain Dell Station of the U. S. Weather Bureau.

History of Development

The canyon was probably first explored by persons of European ancestry in the 1820's. Initial exploration of the canyon must have been by mountain men in search of beaver pelts. However, to the writer's knowledge, these first traverses of the area were not recorded, and visible signs of these early trappers' activities are not recognized within the canyon today.

Alterations to the landscape of the canyon, which are still visible today, were made by the Donner-Reed party of pioneers in 1846. In the summer of that year, this party of California-bound immigrants camped near Henifer, Utah, while they searched for a new wagon road through the Wasatch Mountains. The prior-traversed route down Weber Canyon was impassable because of summer floods within that canyon. These immigrants were forced to construct a new road. This road was built from their camp near Henifer into the East Canyon drainage, over Big Mountain, over Little Mountain, and into Emigration Canyon. The many days spent by the Donner-Reed party in cutting the road out of the heavy brush was very costly to them. This delay resulted in their being trapped by an unusually early snowstorm as they attempted to cross the Sierra Nevada into California. Portions of the trail cut by members of the Donner-Reed party have never grown over and can be observed within the canyon today.

In July 1847, the first wagon train of Mormon pioneers used this already existing road with comparative ease to reach the Salt Lake Valley. A monument at their last campsite has been placed about half-way up Emigration Canyon and is readily visible from the present road. The use of this trail through the canyon by the pioneers gave the canyon its name.

Within the first days of settlement of the Salt Lake Valley in 1847, the waters of Emigration Creek were diverted onto the parched soils and were first used for irrigation. It was with this first use of the water that water rights were established in the valley.

The first settlements within the canyon were made by "squatters" prior to the 1890's (F. J. Meik, personal communication, 1966). The land was not open to filing with the U. S. Government, so the settlers simply moved onto the land and used it as if it were their own. Almost all the floor of the canyon was settled in this manner. The stream was diverted, and the brush and trees cleared. Fields and pastures soon lined the canyon stream. Even some of the higher benches that no longer show obvious signs of cultivation were irrigated by spring flows of smaller tributary streams, and alfalfa and pasture grasses were raised.

It was in this manner that water rights were established within the canyon at an early date by persons not owning the land. Later in the 1890's, the land within the canyon was opened to filing by the U. S. Government, and the "squatters" had preference in filing on the land.

During the early 1900's, an electric railroad was built up the canyon by LeGrand Young to haul building stone out of the canyon. The stone was produced from quarries in the Nugget Sandstone near Pinecrest.

This railroad made the canyon more accessible, and, as a result, many summer homes were soon built within the canyon. It was also at this time that the Pinecrest resort was built at the upper terminus of the railroad.

The first settlers and the owners of the summer homes obtained their domestic water from springs, directly from the creek, from shallow sumps, or from dug wells near the creek. The first deep well in the canyon was constructed in about 1903 on the Meik property in the W½ sec. 32, T. 1 N., R. 2 E. This dug well was "dynamited into solid limestone" to a depth of 120 feet (F. J. Meik, personal communication, 1966).

Two springs near the mouth of the canyon in the N½ sec. 11, T. 1 S., R. 1 E. were put to a special use early in this century. The water from Wagner Springs was used in the Wagner Brewery at the mouth of the canyon, and the water was also piped to what is now Rotary Park for use in a beer garden. The water from the other spring in this section was used by an irrigation company. Salt Lake City obtained the water rights to this spring from the irrigation company and drilled a tunnel back into the mountain to obtain additional water. Since that time, the spring has been known as Emigration Tunnel Springs and has been used by the city in its water system.

The first drilled wells were reported (F. J. Meik, personal communication, 1966) to have been constructed by Salt Lake City just upstream from Emigration Tunnel Springs. Two or three wells were drilled in about 1912. The wells were located in a lime quarry and were drilled into the Twin Creek Limestone. They were not very successful, and it was reported by Mr. Meik that the pumping of the wells interfered with the natural flow of Emigration Tunnel Springs. The use of the wells was soon discontinued.

The records of the Utah State Engineer's Office indicate that it was 36 years before additional drilled wells were constructed in the canyon. In the fall of 1948, F. T. Meik had a well constructed to supply water to several homes in an area he was subdividing. In the 18 years that have elapsed since 1948, more than 120 wells have been drilled. Almost all these wells have been drilled near the stream channel to provide water for domestic purposes.

Present Population

The author estimates that there are about 660 residents in the canyon; of these, about 400 are full-time residents, and about 260 are part-time residents. This does not include the residents of two apartment houses newly constructed just within the study area at the mouth of the canyon.

There are about 165 homes within the canyon. Information provided by Mr. B. O. Goddard, who is the president of the home owner's association in the canyon, indicates that there are about 140 dwellings in the canyon below the Pinecrest area. The writer estimates that there are about 25 summer homes in the Pinecrest area.

The Mountain Fuel Supply Company reports that there are 140 natural gas connections in the canyon, and the Mountain States Telephone Company lists 115 phone connections within the canyon. From this information and the author's knowledge of the area, it is estimated that about 100 of the homes are inhabited on a year-round basis and 65 of them only in the summer season. To determine the number of people represented in these homes, a factor of four persons per family was used (Nelson, 1956).

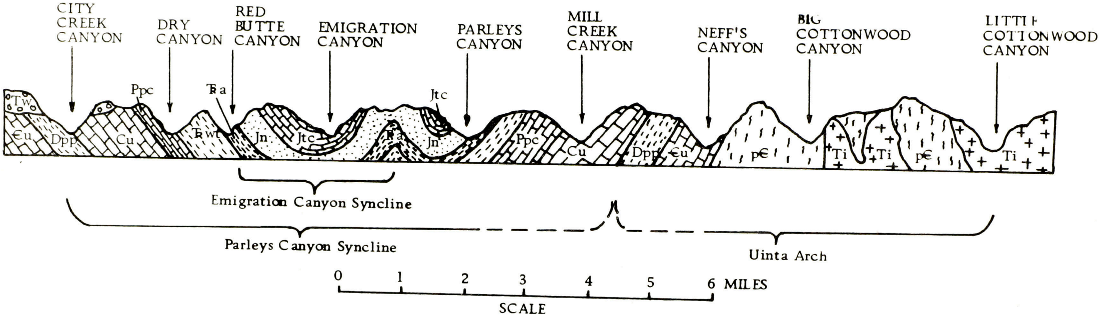
GENERAL GEOLOGY

The rocks of the Wasatch Range in the vicinity of Emigration Canyon were folded by compressional forces 60 to 90 million years ago. In Salt Lake County, the largest structural feature in the Wasatch Range formed by these forces is the Uinta arch (Crittenden, 1964, p.32). The axis of this arch or anticline strikes N. 80° E. and plunges eastward.

North of the Uinta arch and paralleling it, is a large downfold referred to by others as the Parleys Canyon syncline. In the center of the syncline is a small anticline (fig. 3) called the Spring Canyon anticline. The part of the downfold north of the Spring Canyon anticline will be referred to in this report as the Emigration Canyon syncline. The Emigration Canyon syncline affects the movement of ground water within the canyon and is of primary importance to this report.

The axis of the Emigration Canyon syncline corresponds very closely with the stream channel of the canyon in the lower 5 miles of the study area. The axis of the syncline trends about N. 70° E., and plunges eastward. The syncline is lost near the eastern limit of the study area where it is covered by Cretaceous rocks that are younger than the folding (Crittenden, 1964).

There are several known faults in the canyon. Some of these faults are parallel to the axis of the syncline, and others cut it at



EXPLANATION

Ti - Tertiary intrusive rocks

Tw - Tertiary Wasatch Formation

Jtc - Jurassic Twin Creek Limestone

Jn - Jurassic Nugget Sandstone

TRa - Triassic Ankareh Shale

TRwt - Triassic Woodside Shale and Thaynes Limestone

Ppc - Permian Park City Formation

Cu - Carboniferous undifferentiated rocks including the Weber Quartzite and the Madison Limestone

Dpp - Devonian Pinyon Peak Limestone

€u - Cambrian undifferentiated rocks including the Maxfield Limestone, Ophir Shale, and the Tintic Quartzite

p€ - Precambrian rocks

Figure 3.--Diagrammatic geologic cross-section of the Wasatch Mountains in the Emigration Canyon Area. (Modified after H. Schneider)

right angles. None of these faults appear to be of significance to the hydrology of the area and will not be considered further in this report.

The Wasatch Mountains are a giant tilted and eroded fault block elevated within the last 20 million years. The movement along the frontal fault zone near Emigration Canyon was neither as great nor as recent as movement in areas to the north and south of the canyon. The mountain range in the area of Emigration Canyon has a more subdued or mature topography than the range in the Cottonwoods area to the south. The mountain crests are 4,000 feet lower than the area to the south. This indicates that the range in the Emigration Canyon area has not experienced the major recent rejuvenation by fault movement that the loftier segment in the Cottonwoods area has (Marsell, 1964, p. 42).

Figure 4 is a geologic map of the Emigration Canyon drainage that has been adapted from the geologic map of Salt Lake County prepared by R. E. Marsell and R. L. Threet for the Utah Geological and Mineralogical Survey. Only minor alterations were made by the author as a result of field observations.

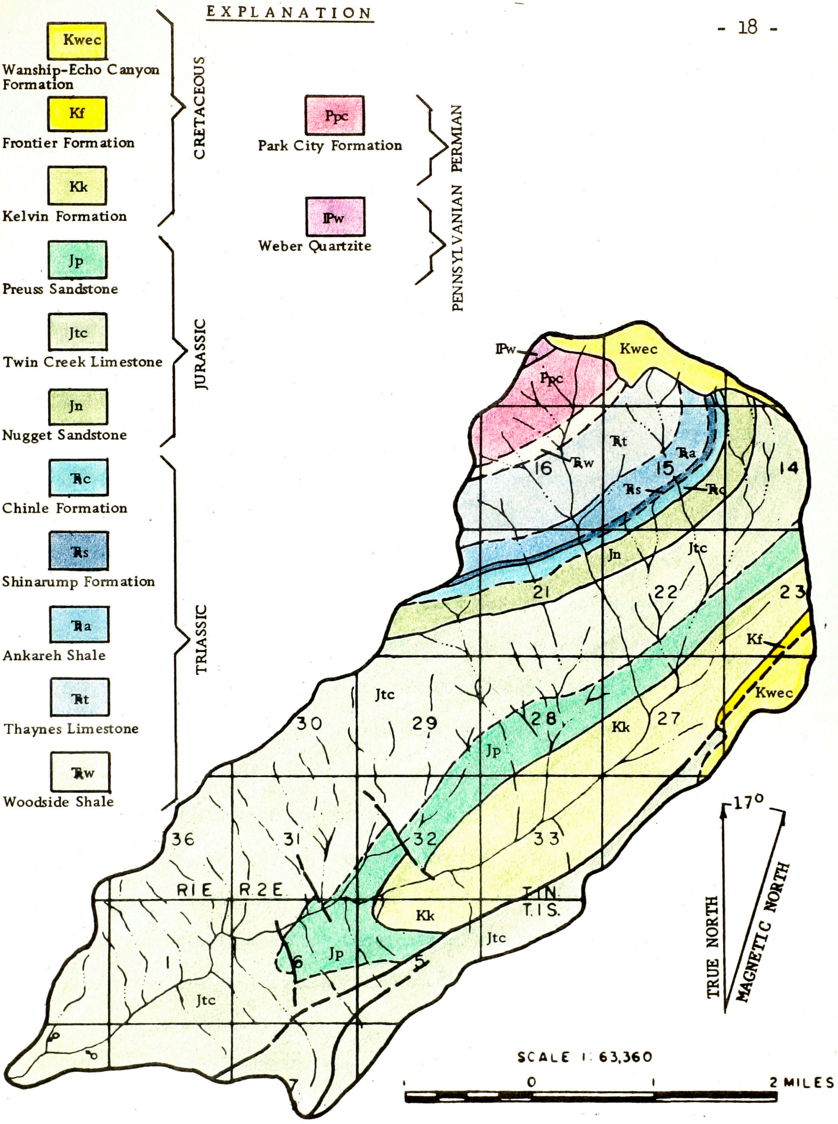


Figure 4.--Geologic map of Emigration Canyon.
(Slightly modified after R.E. Marsell and R.L. Threet)

GEOLOGIC FORMATIONS AND THEIR WATER-BEARING PROPERTIES

General

The geologic formations recognized in the study area range in age from Pennsylvanian to Cretaceous. Only two formations are of Paleozoic age; they are the Pennsylvanian Weber Quartzite and the Permian Park City Formation.

Five formations are of Triassic age; they are the Woodside Shale, Thaynes Limestone, Ankareh Shale, Shinarump Formation, and the Chinle Formation. Three formations are of Jurassic age; they are the Nugget Sandstone, Twin Creek Limestone, and Preuss Sandstone. The three Cretaceous formations in the area are the Kelvin Formation, Frontier Formation, and the Wanship-Echo Canyon Formation.

Widespread unconsolidated Quaternary deposits of slopewash form a shallow blanket or mantle that obscures most of the outcrops of the older formations. Quaternary alluvial deposits are thickest near the stream channel of Emigration Creek.

The Twin Creek Limestone, Preuss Sandstone, and the Kelvin Formation underlie the unconsolidated sediments in most of the area where well development has taken place, and their water-bearing properties are important to the ground-water hydrology of the canyon.

Twin Creek Limestone

The Twin Creek Limestone was deposited at the bottom of a shallow inland sea as a limy ooze and mud in Middle and Late Jurassic times. In the Wasatch Mountains, the formation is about 3,000 feet thick. The limestone is commonly pale grey in color; however, thin beds of red shale occur within the formation in Emigration Canyon.

The formation ranges from a massive, relatively resistant limestone to a thin-bedded, incompetent shale. The massive limestone is strongly jointed, and the bedding planes are well defined (fig. 5). The joints, bedding planes, and solution channels provide channels for water movement. The more incompetent beds do not have well-defined joints, and the bedding planes are too tight to allow free movement of water (fig. 6). Wells that encounter the massive, strongly-jointed limestone are able to develop water because the limestone acts as an aquifer. Wells are unable to develop water from the incompetent beds because they act as partial aquicludes.

Preuss Sandstone

The Preuss Sandstone was deposited as a dark red sand and mud in Late Jurassic time in salty estuaries or lagoons. In the Wasatch Mountains, the formation is about 1,000 feet thick.

The Preuss Sandstone is composed mainly of red silty sandstones, mudstones, and shales (fig. 7). The sandstones are not clean enough or coarse grained enough to be satisfactory as an aquifer. The shales and mudstones are too fine grained to allow free movement of water through them. The water movement in the formation is mainly limited to fractures, joints, and openings along the bedding planes.

Figure 5.--Photo of massive, resistant, steeply-dipping and strongly-jointed Twin Creek Limestone about 1.7 miles above the mouth of Emigration Canyon.

Figure 6.--Photo of incompetent, limy-shale bed of Twin Creek Limestone about 2 miles above the mouth of Emigration Canyon.

Figure 7.--Photo of sandstone bed in the Preuss Sandstone about 3 miles above the mouth of Emigration Canyon.

Kelvin Formation

The Kelvin Formation was deposited upon the fine-grained Preuss Sandstone in Early Cretaceous time as alternating layers of limy mud, red mud, red sands, and coarse conglomerates. These sediments were deposited as a result of the erosion of newly formed highlands to the west. This formation, which is about 1,600 feet thick, has been divided by Crittenden (1963) into two members.

The lower 100 feet of the Kelvin Formation has been designated as the Parleys Member. It is composed of prominent, white, nodular limestone; lavender-grey siltstone and sandstone; and coarse conglomerate (fig. 8). This member was previously referred to by others as the Morrison Formation until it was correlated with other areas and determined to be of Cretaceous and not Jurassic age.

The bulk of the upper member consists of pale red to reddish-brown sandstones and siltstones in alternating beds ranging from a few feet to 20 feet in thickness. At the base of this member and also scattered throughout the member are cobble and boulder conglomerates. These conglomerates are well cemented in places and form prominent, resistant outcrops.

The Parleys Member is too fine grained to be a good aquifer. Siltstones and sandstones of the upper member are also fine grained, and most of the water movement in them must be confined to the secondary openings. Locally, coarse conglomerates may allow the movement of water through the formation; however, the conglomerates are mostly well cemented, and the openings that would allow water movement around

Figure 8.--Photo of the red Preuss Sandstone (left) and the Parleys Member of the Kelvin Formation (right) in a road cut about 3.4 miles above the mouth of Emigration Canyon.

the cobbles and boulders are small and few. Outcrops of the well-cemented conglomerates display prominent and large open joints that would allow free movement of water (fig. 9).

Quaternary Deposits

A mantle of unconsolidated material of Quaternary age covers most of the area. Stream deposits of this age reach a maximum thickness at the bottom of the valley. Well logs indicate that the unconsolidated alluvial deposits of Quaternary age have accumulated to an average depth of about 50 feet near the stream channel. The stream deposits are commonly poorly sorted and very coarse. They are predominantly red in color, and in road cuts, cobbles and boulders are prominent (fig. 10).

Figure 9.--Photo of a well-cemented, resistant boulder conglomerate in the upper member of the Kelvin Formation. Note the prominent joints. Photo was taken about 6 miles above the mouth of Emigration Canyon.

Figure 10.--Photo of alluvial deposits exposed in a road cut about 3.2 miles above the mouth of Emigration Canyon.

SURFACE WATER

Stream Flow

The annual flow of Emigration Creek past the stream gage near Hogle Zoo over the last 65 years has averaged about 4,340 acre-feet (table 1). The highest flow on record was in 1910 when 13,500 acre-feet of water was measured; the lowest flow on record was in 1961 when 234 acre-feet of water was measured. The gage is at an altitude of 4,870 feet, and there are about 29 square miles of drainage above the gage. The average yield per square mile annually is 149 acre-feet.

Stream discharge varies greatly from year to year and season to season. Usually, the greatest discharge is in the months of March, April, May, and June (fig. 11). Seasonal discharge (March 1st to July 1st) does not vary directly with precipitation on the watershed. Runoff that results from precipitation depends upon the intensity of the storm, the form of the precipitation, the season of the year, as well as residual soil moisture in the thick mantle found almost everywhere in the canyon. R. W. Evans (1953) found that the runoff from heavier than average seasonal precipitation (October 1st to June 1st) may be delayed as long as two years until deficits in the soil moisture are made up. Evans also found that a very heavy spring runoff is strongly dependent on climatic factors in addition to precipitation. Figure 12 is taken directly from his unpublished master's thesis. It should be noted that the years of very heavy runoff, 1921, 1922, and 1952, were years when precipitation was not greater than several years when the stream flow was near average.

TABLE 1.--Emigration Creek discharge at the gage near Hogle Zoo. Data from unpublished records of the Department of Water Supply and Waterworks, Salt Lake City, Utah

Year	Annual flow in acre-feet	Year	Annual flow in acre-feet	Year	Annual flow in acre-feet
1901	2,320	1923	6,020	1945	2,640
1902	2,050	1924	2,300	1946	2,360
1903	2,310	1925	3,010	1947	3,950
1904	4,540	1926	3,620	1948	4,720
1905	1,740	1927	4,520	1949	5,460
1906	3,390	1928	4,770	1950	6,260
1907	5,950	1929	6,090	1951	4,748
1908	3,370	1930	1,940	1952	11,327
1909	10,700	1931	1,190	1953	6,037
1910	13,500	1932	3,560	1954	1,305
1911	1,750	1933	3,320	1955	1,720
1912	4,490	1934	681	1956	2,284
1913	5,740	1935	1,700	1957	4,518
1914	5,110	1936	6,310	1958	6,528
1915	2,340	1937	4,600	1959	1,508
1916	3,910	1938	4,400	1960	2,079
1917	6,610	1939	2,940	1961	234
1918	3,650	1940	2,660	1962	2,675
1919	3,050	1941	3,660	1963	1,891
1920	6,350	1942	6,190	1964	5,416
1921	12,300	1943	3,240	1965	8,355
1922	11,500	1944	3,080		

Total of 65 years of runoff-------281,832 acre-feet
Average annual runoff---------------4,336 acre-feet
Lowest annual runoff-----------234 acre-feet (1961)
Highest annual runoff-------13,500 acre-feet (1910)

Elevation of gage------------------------4,870 feet
Drainage area-----------------------29 square miles
Average yield per square mile---------149 acre-feet

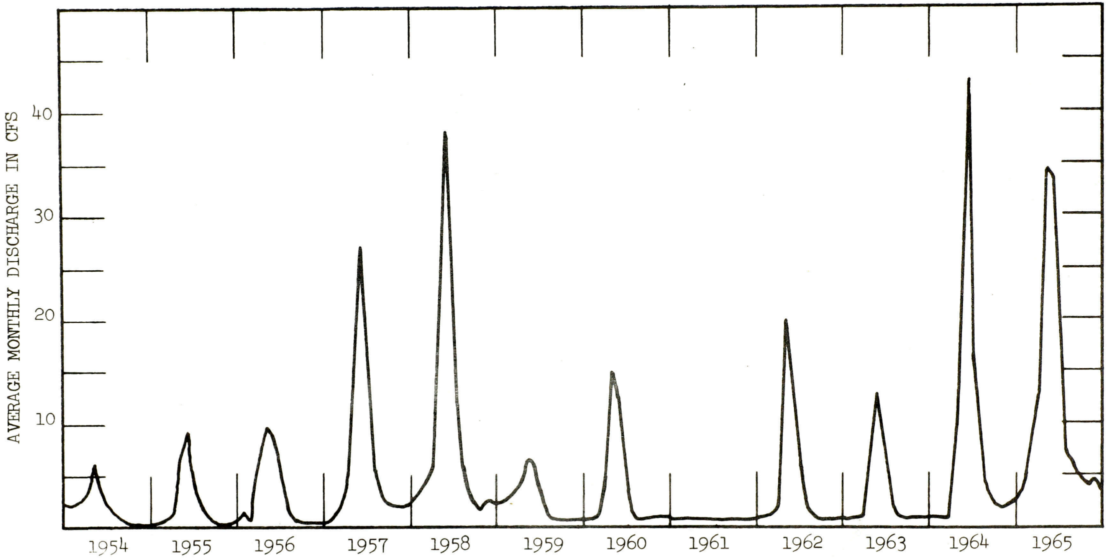


Figure 11.--Average monthly stream discharge in cfs of Emigration Creek at the stream gage near Hogle Zoo from 1954-65
(Information provided by Salt Lake City)

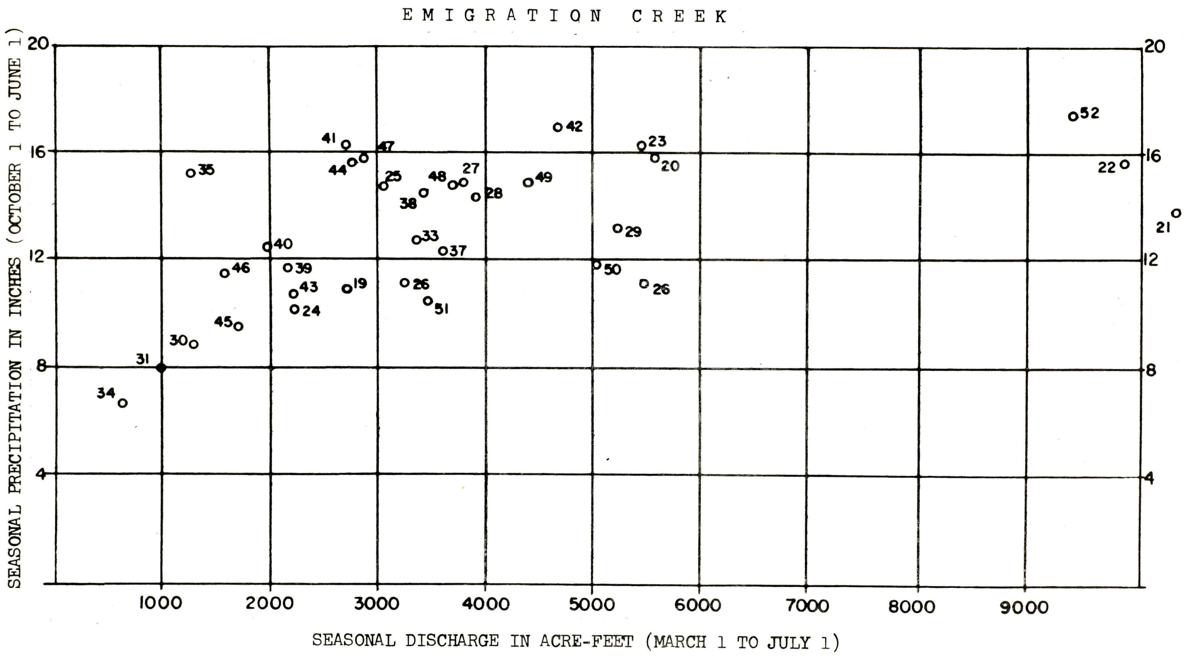


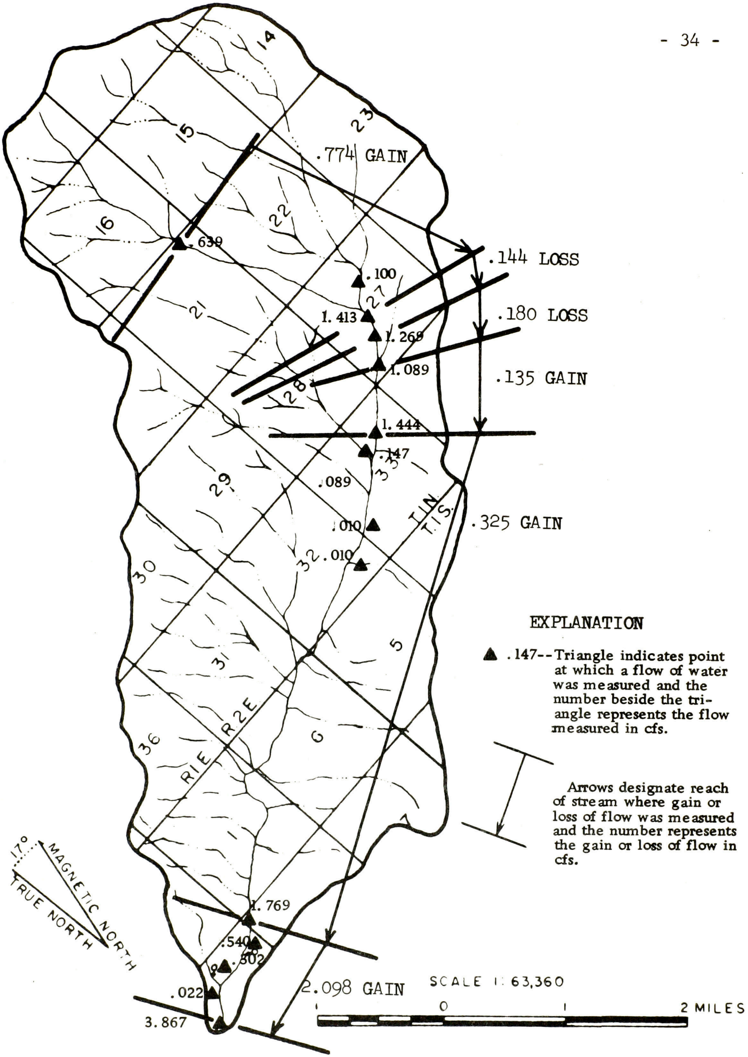
Figure 12.--Graph showing seasonal discharge of Emigration Creek in acre-feet plotted against seasonal precipitation. (Slightly modified from R. W. Evans, unpublished master's thesis, 1952) Numbers plotted represent years, 1919 to 1952.

The flow of the creek was measured at several points by C. A. Horr of the U. S. Geological Survey on August 9 and 10, 1965, to determine the seepage of water into or out of the stream. The results are shown in figure 13. It was found that the stream is an effluent stream in portions of the canyon and an influent stream in other portions at the same season of the year. It was noted that the stream lost nearly one-half of a second foot of water in about one-third of a mile in sec. 27, T. 1 N., R. 2 E. On the other hand, more than half the flow of the stream was gained in the last mile of stream channel above the gage. Most of the gain is from ground-water sources.

Chemical and Biological Water Quality and Water Temperature

Samples of water from the creek were collected for chemical analyses at the stream gage just above Hogle Zoo and at a point about 5 miles further upstream in (A-1-2)27cad. The analyses indicate that the water in the stream is of the calcium bicarbonate type and is classified as very hard (table 2). Except for hardness, the water is of a chemical quality that is suitable for most uses.

In addition to the two analyses reported in table 2, the specific conductance of Emigration Creek was determined at three points between the upper sampling point and the stream gage. The samples and specific conductance determinations indicate that the creek picks up a small amount of additional dissolved solids as it flows downstream. Magnesium and sulfate are the major constituents added to the water.



EXPLANATION

▲ .147--Triangle indicates point at which a flow of water was measured and the number beside the triangle represents the flow measured in cfs.

Arrows designate reach of stream where gain or loss of flow was measured and the number represents the gain or loss of flow in cfs.

Figure 13.--Map showing the results of a seepage run in Emigration Creek, Aug. 9-10, 1965.

TABLE 2.--Chemical analyses of water from Emigration Creek, Emigration Tunnel Springs, and 9 selected wells in Emigration Canyon

(Source of water: 1, Emigration Creek; 2, Emigration Tunnel Springs; 3, well)

Location of Sampling[1] and Owner	Source of water	Date of collection	Depth of well (ft.)	Parts per million											Percent sodium	Sodium-adsorption-ratio (SAR)	Specific conductance (micromhos per cm at 25° C)	pH
				Silica (SiO_2)	Calcium (Ca)	Magnesium (Mg)	Sodium and potassium (Na+K)	Bicarbonate (HCO_3)	Sulfate (SO_4)	Chloride (Cl)	Nitrate (NO_3)	Total dissolved solids	Hardness as $CaCO_3$	Noncarbonate hardness as $CaCO_3$				
(D-1-1)11bcc ------	1	9-20-65	---	10	62	34	24	231	112	29	0.1	439	295	106	15	0.6	715	7.9
(D-1-1)11aa[2] Salt Lake City	2	1963-64	---	15	133	26	23	309	212	23	2.9	617	466	218	--	---	904	7.6
(D-1-1)1cdc-2 E. Fitzgerald	3	9-10-65	106	14	107	35	23	350	115	36	2.3	563	410	123	11	0.5	813	7.8
(D-1-1)1dbd-4 C. Penman	3	--do---	129	11	86	17	24	311	44	25	0.3	381	284	29	16	0.6	611	7.7
(D-1-1)1dab-1 R. Evans	3	11-3-58	65	13	127	8	60	445	54	55	1.0	542	354	11	--	---	---	7.1
(A-1-2)32dad-2 E. Parker	3	9-20-65	65	13	99	44	31	390	58	81	0.7	608	428	108	14	0.6	913	7.8
(A-1-2)33acc-3 W. Ashley	3	9-8-58	45	13	130	4	26	375	51	27	0.9	441	324	---	--	---	---	7.3
(A-1-2)33aaa-2 A. Roberts	3	9-10-65	135	11	94	39	29	408	51	27	0.9	524	394	59	14	0.6	829	8.0

TABLE 2.--Chemical analyses of water from Emigration Creek, Emigration Tunnel Springs, and 9 selected wells in Emigration Canyon--Continued

(Source of water: 1, Emigration Creek; 2, Emigration Tunnel Springs; 3, well)

Location of Sampling and Owner	Source of Water	Date of collection	Depth of well (ft.)	Parts per million											Percent sodium	Sodium-adsorption-ratio (SAR)	Specific conductance (micromhos per cm at 25° C)	pH
				Silica (SiO2)	Calcium (Ca)	Magnesium (Mg)	Sodium and potassium (Na+K)	Bicarbonate (HCO3)	Sulfate (SO_4)	Chloride (Cl)	Nitrate (NO_3)	Total dissolved solids	Hardness as CaCO3	Noncarbonate hardness as CaCO3				
(A-1-2)27cad ------	1	2-17-65	---	10	83	16	14	231	112	29	0.1	439	295	106	15	0.6	715	7.9
(A-1-2)27bdd-3 K. Struhs	3	9-10-65	405	16	81	27	33	359	34	39	0	456	313	19	19	0.8	761	7.9
(A-1-2)27bdd-3 K. Struhs	3	9-10-65	120	17	867	526	4,280	15	444	9,310	16	16,900	4,330	4,310	68	28	24,800	6.9
(A-1-2)16dac-1 B. Shipler	3	9-21-65	196	13	439	108	67	296	1,360	19	0.2	2,290	1,540	1,300	9	0.7	2,380	8.0

[1] Analyses are listed in sequence by location with the sample collected from the source lowest in the canyon first, and the sample collected from the source highest in the canyon last.

[2] Average of samples from Emigration Tunnel Springs collected and analyzed almost every day by Salt Lake City during 1963 and 1964.

Numerous samples from the stream collected and analyzed by the Salt Lake County Board of Health to determine the number of coliform bacteria present show the stream to be highly contaminated. The most probable number of coliform bacteria per 100 milliliters reported in 92 samples collected in 1964-65 ranged from 91 to 430,000 bacteria and averaged 16,512. The most probable number of coliform bacteria per 100 milliliters is determined by actually counting the bacteria in a much smaller amount of water under a microscope. These figures indicate that the water is highly contaminated, and only the most up-to-date water treatment plants can render the water fit for culinary use.

By the standards of the Utah State Board of Health, waters with this amount of bacterial contamination are Class E waters. Class E waters should not be used for domestic supply or any form of irrigation including lawn watering because of health hazards. The use of waters of this class should be limited primarily to the transportation of waste (Calvin Sudweeks, personal communication, 1966).

Coliform bacteria exist in the intestines of both animals and man. Their presence in the stream represents the discharge of animal and human waste into the stream. Corralling of livestock adjacent to, and in some cases, across the stream is a source of part of the contamination. Additional contamination is also coming from direct sewage discharge into the stream from residences in the canyon that have been reported to the author. In addition, many of the septic tank facilities are reported not to have adequate drain fields because of their location adjacent to the stream, and contamination from this source is almost certain.

The temperature of Emigration Creek was observed at four points on a regular basis during the study, and spot measurements were made at additional points. The locations of the regular observation points are identified by figure 14. Stream temperatures are listed in table 3 and identified by the location number given on figure 14. Observations of the temperature of the water from wells and springs were also made in an effort to see if comparisons could be made and an insight gained of the relationship between the surface water and the ground water. The comparison of stream, spring, and groundwater temperatures will be made in later sections of the report.

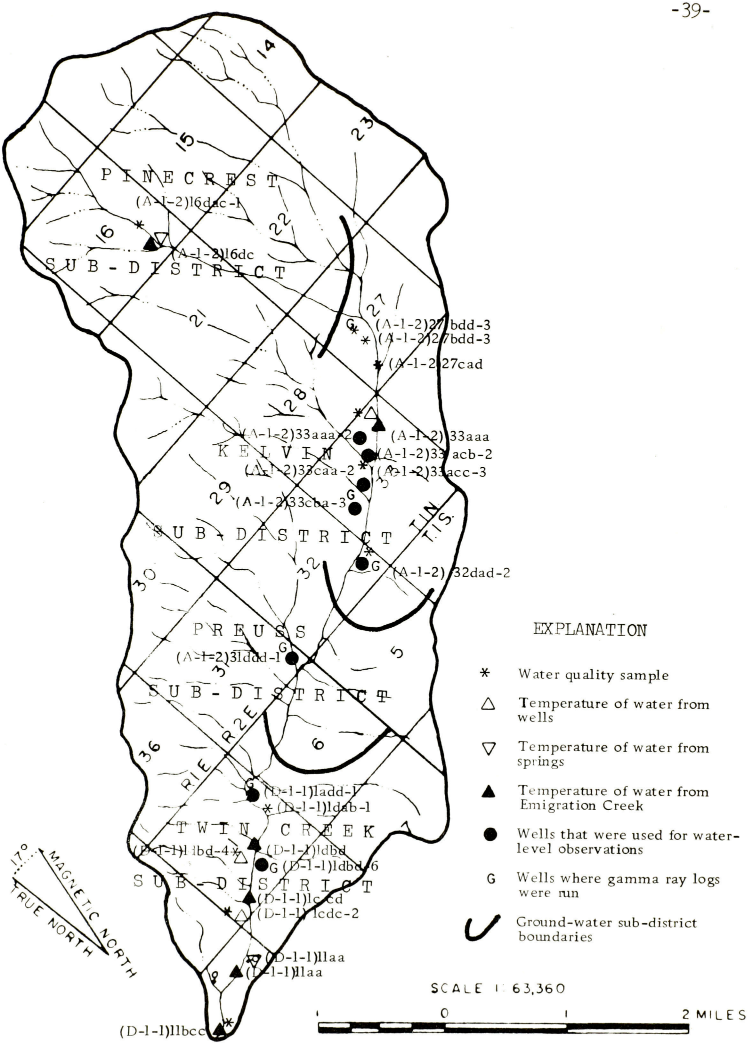


Figure 14. --Map showing the points at which temperature, chemical quality, water level, and gamma ray log information was obtained and the ground-water sub-districts in Emigration Canyon.

TABLE 3.--Water temperatures in degrees Fahrenheit taken at various locations on Emigration Creek, wells, and springs

Date	Emigration Creek						Wells			Springs	
	(D-1-1)11bcc	(D-1-1)11aa	(D-1-1)1ccd	(D-1-1)1dbd	(A-1-2)33aaa	(A-1-2)16dc	(D-1-1)1cdc-2	(D-1-1)1dbd-4	(A-1-2)33aaa-2	(D-1-1)11aa	(A-1-2)16dc
6- 25-65	52°		52°	54°			56°	49°			
7- 14-65	56°		56°	54°	54°	52°	55°	50°	50°		50°
7- 20-65				59°				50°			
8- 17-65	59°			60°		52°		51°			50°
9- 10-65			55°	54°	53°		55°		47°		
9- 20-65	46°	47°	40°	40°		44°	54°	53°		54°	
10-21-65	48°		42°	42°	42°		55°	52°	48°		
12- 1-65	43°		34°	34°	34°		57°	50°	46°		
1-- 6-66	43°		36°	36°			56°	50°			
2- 18-66	40°	33°*	33°*	33°*	33°*		56°	49°	46°	54°	
3- 15-66	39°		37°	36°	36°		54°	50°	46°		

*Surface of stream was frozen over, but water flowing below the ice surface was estimated to be between 32° and 34°

GROUND WATER

Ground-Water Sub-Districts

For the purpose of ground-water study, the author will refer to the area as the Emigration Canyon district of Salt Lake County. This district was divided into four sub-districts--the Twin Creek sub-district, Preuss sub-district, Kelvin sub-district, and the Pinecrest sub-district. The location of these sub-districts can be seen in figure 14.

The boundaries of the sub-districts were determined primarily by the contacts of the geologic formations (fig. 4). The lithology and the hydrologic conditions in each of the sub-districts differ because of the hydrologic characteristics of the formations that underlie the unconsolidated mantle and the effects that the dip of the beds have on ground-water movement.

Springs

General.--Wagner Springs and Emigration Tunnel Springs are the largest springs in the study area. They occur in the Twin Creek sub-district near the mouth of the canyon. In other parts of the canyon springs are not numerous, and the discharge from most of them is small. A few springs issue from alluvial material in or near stream channels. Most of these springs were developed by individuals who have collected the water for domestic use. These springs generally serve only one to a few families. Some springs occur at points along stream channels where the alluvial valley fill cover over the bedrock thins.

The thick mantle, which is present over most of the area, absorbs a very high percentage of the water that falls on the surface. It also provides a medium in which the water can move downslope and down the canyon without coming to the land surface. Additional water moves into the bedrock, primarily by flow in open joints. This water will not reappear at the land surface until geologic and hydrologic conditions force it to the surface.

Wagner Springs.--Wagner Springs, (D-1-1)11ab, are in a small side canyon to the north of the main canyon. Early use of this water has been discussed in the "History of Development" portion of this report. Water is presently impounded in a large storage tank, and part of it is used in the small Rotary Park at the mouth of the canyon and in the maintenance of the grounds at the "This Is the Place" Monument. Unused water is allowed to overflow the reservoir, and the overflow contributes to the creek.

The temperature of the outfall from the storage tank was 47° on February 18, 1966, and was warmer than the creek water on this day. The stream temperature above the inflow of Wagner and Emigration Tunnel Springs was about 33°. The temperature of the outfall from the storage tank was lower than the true temperature of the springs, because the 32° air temperature on the day of the observation would have modified the temperature of the water. The temperature of the water suggests that it is coming from deep ground-water sources, perhaps from the Twin Creek Limestone.

In August 1965, when the seepage run was conducted (fig. 13), the overflow from the storage tank was contributing almost one-third of a second foot of water to the creek. Water from the spring was being put to additional, unmeasured uses on that day, so this does not represent the total flow of the springs. It has been reported that the flow of Wagner Springs is not as dependable as the flow of Emigration Tunnel Springs, and that it varies from year to year and from season to season (Charles Wilson, personal communication, 1966).

Emigration Tunnel Springs.--Emigration Tunnel Springs are located in (D-1-1)11aa and upstream from Wagner Springs on the opposite side of the creek. It is a developed spring, or perhaps it could more descriptively be called a horizontal well. History of its development was discussed briefly in an earlier section of the report. Water from the spring is used by Salt Lake City, and the amounts consumed by the City yearly from 1961 to 1964 are given in table 4. The spring supplies the City with slightly more than 2 per cent of its water supply.

The temperature of the water issuing from the spring was 54° on September 20, 1965, and February 18, 1966. While the two temperature readings of the springs did not vary, the stream temperature during this period varied 14 degrees from 47° to 33°.

The temperature of the spring water going into the Salt Lake City water line is observed almost daily by the City. The monthly average of temperatures observed by the City is given in table 5 for each month from January 1963 to December 1965. The average water temperature for each year is also given. The City also makes a chemical

TABLE 4.--Discharge and use of water from Emigration Tunnel Springs, 1961-64

	Year			
	1961	1962	1963	1964
	Acre-feet			
Water collected by Salt Lake City into pipe line from Emigration Tunnel Springs.	1,001	1,382	1,301	1,594
Water discharged into Emigration Creek from Emigration Tunnel Springs.	0	58	0	339
Total flow of Emigration Tunnel Springs	1,001	1,440	1,301	1,933
	Second-feet			
Average flow of springs.	1.4	2.0	1.8	2.7
Maximum flow of springs.	2.5	3.2	2.7	4.6
Minimum flow of springs.	0.8	0.8	1.3	1.2

analysis of the spring water almost every day. The averages of the analyses for the years 1963-64 are given in table 2.

The records of the discharge of Emigration Tunnel Springs as measured by Salt Lake City indicate that the spring has an annual peak flow in the early summer, but at a later date than the peak discharge of the canyon stream. The increased flow of the springs occurs over a longer period of time than the increased flow of the stream. The peak is not as prominent in the hydrograph of the springs as the peak in the hydrograph of the stream (Eldon T. McEntire, personal communication, 1966).

TABLE 5.--Monthly average of water temperature readings from Emigration Tunnel Springs, 1963-65

Year	Jan	Feb	Mar	Apr	May	Je	Jul	Aug	Sept	Oct	Nov	Dec	Average
	Temperature in degrees Fahrenheit												
1963	54	52	54	52	54	54	53	54	54	52	53	53	53.25
1964	52	52	53	54	52	54	53	54	52	52	56	54	53.17
1965	52	54	53	53	53	52	54	54	51	53	52	50	52.58

The tunnel or drain has been constructed at right angles to the canyon and penetrates into the wall of the canyon a distance of 750 feet. For most of its length, it is in Twin Creek Limestone. A log of the tunnel, prepared and provided to the writer by R. E. Marsell, is shown in figure 15. Almost all the water flowing from the tunnel is being contributed by a fracture zone in Twin Creek Limestone near the terminal end of the tunnel.

Wells

Number and locations.--About 120 logs of wells drilled within the study area are on file in the Utah State Engineer's Office. In addition to this, there are several dug wells and sumps of which only a few have been placed on record in the State Engineer's Office. Almost without exception, the wells are located within a narrow band that extends for most of the length of the canyon. Nearly all the wells are located on the valley floor and within one-quarter of a mile of Emigration Creek.

Logs of 37 wells in the Twin Creek sub-district are on file in the State Engineer's Office, 12 wells in the Preuss sub-district,

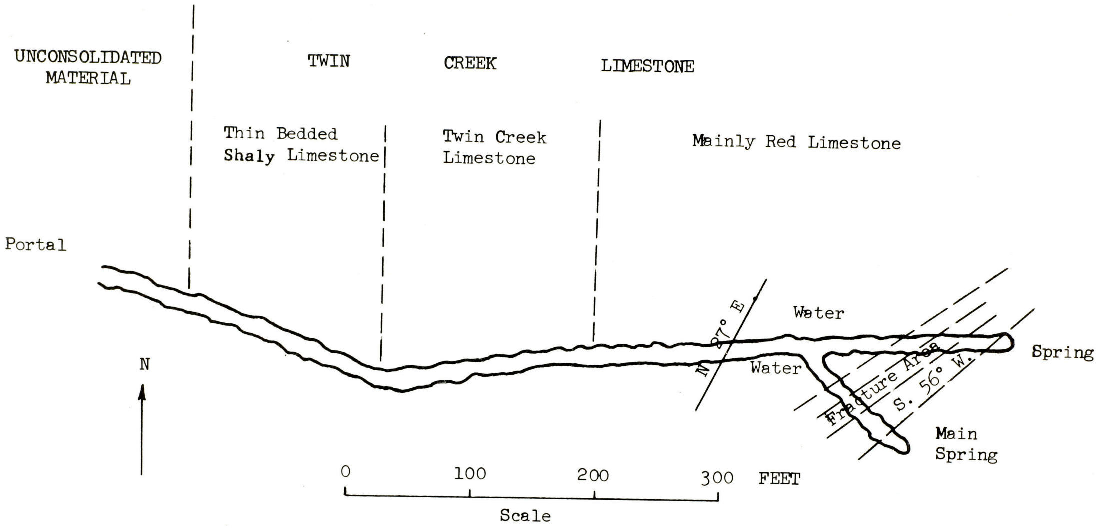


Figure 15.--Map of Emigration Tunnel Springs.
(Information provided by R. E. Marsell)

65 wells in the Kelvin sub-district, and 4 wells in the Pinecrest sub-district. Locations of these wells to within a ten-acre tract are given in table 6.

Water levels and artesian pressures.--Most of the well drillers' reports on file list the water level that was observed by the driller at the time the well was completed. Well drillers' reports also indicate the diameter and length of casings used and the depths at which perforations were constructed in the well casings. Drillers have reported in almost every well that the water levels rose above the perforations. This shows that the water encountered was under artesian pressure. The height that the water rose in the well casing above the highest perforation has been termed artesian pressure in table 6. This is not an accurate measurement of the artesian pressure within the aquifer, however, because several factors associated with well construction could alter the water level observed by the well driller. This figure is also dependent upon an accurate water-level observation by the driller as well as an accurate description of the locations of the perforations. It does, however, give the correct order of magnitude of the artesian pressures present in the aquifers.

Water-level observations of 8 wells were made periodically during the study. The water levels observed are shown by hydrographs in figure 16, and the locations of these observation wells are shown in figure 14. The five observation wells in the upper reaches of the canyon are in the Kelvin sub-district. The water levels in the wells in the Kelvin sub-district fluctuated less than the water levels in the

TABLE 6.--Location, depth, aquifer, reported water level rise above perforations, reported production in gallons per minute, and calculated specific capacities of wells in Emigration Canyon that have well drillers' reports on file with the Utah State Engineer's Office

Well location	Depth (ft.)	Aquifer material	Rise above perforations (ft.)	Production (gpm)	Specific capacity (gpm per foot of drawdown)
Twin Creek sub-district					
(D-1-1)11aca-1	250	Twin Creek	--	12	4.00
(D-1-1)11aca-2[4]	245	----do----	39	75	0.33
(D-1-1)1ccd-1	106	Valley fill	10	30	6.00
(D-1-1)1cdc-4[5]	121	Twin Creek	65	--	----
(D-1-1)1cdc-4	93	----------	3	25	4.00
(D-1-1)1cdc-3[5]	108	Valley fill	40	20	5.00
(D-1-1)1cdc-3	65	----do----	12	--	----
(D-1-1)1cdc-2[3,4]	76	----do----	15	35	2.30
(D-1-1)1cdc-6	105	Valley fill and Twin Creek	10	25	2.50
(D-1-1)1cdc-1	90	Valley fill	19	5	1.25
(D-1-1)1cdb-3	105	Twin Creek	20	15	1.50
(D-1-1)1cdb-2	97	----do----	15	15	5.00
(D-1-1)1cdb-1	102	Valley fill	3	20	----
(D-1-1)1cdc-5	101	Twin Creek	24	30	7.50
(D-1-1)1cdd-5	82	----do----	17	18	2.60
(D-1-1)1cda-4	114	----do----	15	20	1.30
(D-1-1)1ccc-1	140	Valley fill	4	20	2.00
(D-1-1)1cda-2	92	Twin Creek	30	20	2.00
(D-1-1)1cdd-2[5]	65	Valley fill	21	--	----
(D-1-1)1cdd-2	88	Valley fill and Twin Creek	2	20	----
(D-1-1)1cdd-1[5]	92	Twin Creek	-1	25	2.50
(D-1-1)1cdd-1	58	----do----	-6	25	----
(D-1-1)1cda-1	65	Valley fill	10	25	5.00
(D-1-1)1cdd-3	75	Twin Creek	19	26	1.70

See footnotes at end of table

TABLE 6.--Location, depth, aquifer, reported water level rise above perforations, reported production in gallons per minute, and calculated specific capacities of wells in Emigration Canyon that have well drillers' reports on file with the Utah State Engineer's Office--Continued

Well location	Depth (ft.)	Aquifer material	Rise above perforations (ft.)	Production (gpm)	Specific capacity (gpm per foot of drawdown)
		Twin Creek sub-district--Continued			
(D-1-1)1cdd-4	85	Twin Creek	15	20	1.30
(D-1-1)1dcb-2	85	Valley fill	0	5	----
(D-1-1)1dbc-4	112	Twin Creek	15	18	1.20
(D-1-1)1dbc-2	97	Valley fill	-1	5	----
(D-1-1)1dbc-3	152	Twin Creek	60	25	2.50
(D-1-1)1dbd-5	120	----do----	20	15	0.75
(D-1-1)1dbd-3	126	----do----	34	25	5.00
(D-1-1)1dbd-2	113	----do----	28	25	5.00
(D-1-1)1dbd-6[1,2]	152	----do----	18	20	1.30
(D-1-1)1dbd-4[3,4]	129	----do----	--	20	4.00
(D-1-1)1dbc-1[4]	132	----do----	--	10	----
(D-1-1)1dbc-1[5]	150	----do----	12	100	4.40
(D-1-1)1dbd-1	102	Valley fill	--	5	----
(D-1-1)1dac-1	138	Twin Creek	-6	--	----
(D-1-1)1dab-1[4]	65	Valley fill and Twin Creek	27	--	----
(D-1-1)1dab-3	73	Twin Creek	50	22	3.10
(D-1-1)1daa-1	65	Valley fill	26	60	6.60
(D-1-1)1dab-4	70	Twin Creek	30	25	5.00
(D-1-1)1daa-2	84	----do----	2	10	----
(D-1-1)1add-1[1,2]	73	Valley fill	20	50	----
Average Twin Creek	122	------------	21	26	2.84
Average Valley fill	85	------------	15	26	4.36

See footnotes at end of table

TABLE 6.--Location, depth, aquifer, reported water level rise above perforations, reported production in gallons per minute, and calculated specific capacities of wells in Emigration Canyon that have well drillers' reports on file with the Utah State Engineer's Office--Continued

Well location	Depth (ft.)	Aquifer material	Rise above perforations (ft.)	Production	Specific capacity (gpm per foot of drawdown)
Preuss sub-district					
(D-1-2)6abd-2	80	Preuss	25	20	1.30
(D-1-2)6abd-1	67	----do----	27	20	5.00
(D-1-2)6aab-1	83	----do----	0	8	0.17
(D-1-2)6aab-2	81	Valley fill	27	20	2.00
(D-1-2)6aab-4	72	Preuss	25	10	1.00
(D-1-2)6aab-5	101	----do----	--	--	----
(D-1-2)6aaa-1	60	----do----	--	--	----
(D-1-2)6aaa-3	105	----do----	17	--	----
(D-1-2)6aaa-2	85	----do----	48	20	1.33
(A-1-2)31ddd-1[1,2]	185	----do----	51	50	3.30
(A-1-2)32ccc-1	101	----do----	--	--	----
(D-1-2)5bbb-1	93	Valley fill and Preuss	29	25	1.30
Average Preuss	94	------------	28	22	2.02
Average Valley fill	81	------------	27	20	2.00
Kelvin sub-district					
(A-1-2)32ccd-1	98	Valley fill	69	30	2.00
(A-1-2)32cdc-1	80	----do----	61	15	0.31
(A-1-2)32cdc-2	110	----do----	48	15	1.50
(A-1-2)32cdd-3	86	----do----	48	20	1.50
(A-1-2)32ccc-1	50	Kelvin	--	2	0.06
(A-1-2)32cdd-2	96	Valley fill	50	20	2.00
(A-1-2)32cdd-4	105	Kelvin	15	15	0.39

See footnotes at end of table

TABLE 6.--Location, depth, aquifer, reported water level rise above perforations, reported production in gallons per minute, and calculated specific capacities of wells in Emigration Canyon that have well drillers' reports on file with the Utah State Engineer's Office--Continued

Well location	Depth (ft.)	Aquifer material	Rise above perforations (ft.)	Production (gpm)	Specific capacity (gpm per foot of drawdown)
Kelvin sub-district-Continued					
(A-1-2)32dcb-3	37	Valley fill and Kelvin	1	30	2.00
(A-1-2)32dcb-2	36	Kelvin	16	25	2.50
(A-1-2)32dca-1	44	----do----	--	7	----
(A-1-2)32ddb-1	16	Valley fill	3	6	3.00
(A-1-2)32dac-1	116	Kelvin	13	20	0.80
(A-1-2)32dac-2	100	----do----	35	25	1.70
(A-1-2)32dad-2[1,2,4]	65	Valley fill and Kelvin	27	20	3.70
(A-1-2)32dad-1	110	Kelvin	45	20	20.00
(A-1-2)33ccc-1	80	Valley fill	40	15	0.75
(A-1-2)33cbd-2	138	Kelvin	45	100	3.70
(A-1-2)33cba-3[1,2]	76	----do----	35	20	5.00
(A-1-2)33cba-2	40	----do----	--	10	----
(A-1-2)33cac-1	108	----do----	--	15	1.50
(A-1-2)33cba-4	72	----do----	42	15	3.00
(A-1-2)33cba-1	113	----do----	60	25	5.00
(A-1-2)33cab-3	52	Valley fill	32	35	----
(A-1-2)33cab-2[5]	155	----do----	41	30	5.00
(A=1-2)33cab-2	25	----do----	--	30	----
(A-1-2)33cab-1	105	----do----	74	20	2.60
(A-1-2)33bcd-1	105	----do----	40	20	1.00
(A-1-2)33bdc-1	137	----do----	--	--	----
(A-1-2)32aad-1	117	Valley fill and Kelvin	37	--	----
(A-1-2)33bdd-2	82	Valley fill	42	20	10.00
(A-1-2)33caa-1	105	Valley fill and Kelvin	32	25	5.00
(A-1-2)33caa-2[1]	90	Kelvin	13	--	----

See footnotes at end of table

TABLE 6.--Location, depth, aquifer, reported water level rise above perforations, reported production in gallons per minute, and calculated specific capacities of wells in Emigration Canyon that have well drillers' reports on file with the Utah State Engineer's Office--Continued

Well location	Depth (ft.)	Aquifer material	Rise above perforations (ft.)	Production (gpm)	Specific capacity (gpm per foot of drawdown)
Kelvin sub-district--Continued					
(A-1-2)33bdd-1	60	Valley fill	1	40	----
(A-1-2)33bdd-4	142	Kelvin	91	20	0.66
(A-1-2)33bdd-5	150	----do----	106	--	----
(A-1-2)33bdd-3	51	Valley fill	18	30	----
(A-1-2)33acc-3[4]	115	----do----	60	15	0.50
(A-1-2)33acb-1	101	Kelvin	42	20	1.30
(A-1-2)33acb-2[1]	120	----do----	37	20	2.00
(A-1-2)33aca-1	65	----do----	22	30	6.00
(A-1-2)33aca-3	165	----do----	119	--	----
(A-1-2)33aac-5	162	----do----	36	--	----
(A-1-2)33aac-2	200	----do----	25	10	0.07
(A-1-2)33aac-3	110	----do----	50	20	0.30
(A-1-2)33aac-1	72	----do----	35	10	1.00
(A-1-2)33ada-2	50	----do----	5	10	----
(A-1-2)33ada-3	118	----do----	28	20	0.50
(A-1-2)33ada-1	50	----do----	--	4	----
(A-1-2)33add-1	62	----do----	--	35	----
(A-1-2)33aaa-2[1,3,4]	135	----do----	100	--	----
(A-1-2)33aaa-1	108	----do----	40	35	3.50
(A-1-2)34bbb-3	111	----do----	66	20	1.25
(A-1-2)34bbb-2	145	----do----	--	--	----
(A-1-2)34bbb-1	112	----do----	53	15	0.30
(A-1-2)27ccc-2	39	Valley fill	--	--	----
(A-1-2)27ccd-1	60	Kelvin	16	50	----
(A-1-2)27ccd-2	90	----do----	17	20	1.30
(A-1-2)27cab-1[5]	180	----do----	--	--	----
(A-1-2)27cab-1	77	----do----	--	40	----
(A-1-2)27bdd-3[4]	405	----do----	--	--	----

See footnotes at end of table

TABLE 6.--Location, depth, aquifer, reported water level rise above perforations, reported production in gallons per minute, and calculated specific capacities of wells in Emigration Canyon that have well drillers' reports on file with the Utah State Engineer's Office--Continued

Well location	Depth (ft.)	Aquifer material	Rise above perforations (ft.)	Production (gpm)	Specific capacity (gpm per-foot of drawdown)
Kelvin sub-district--Continued					
(A-1-2)27bdd-3[2,4,5]	120	Kelvin	15	1	----
(A-1-2)27bdd-2[5]	375	----do----	112	25	0.25
(A-1-2)27bdd-2	65	----do----	30	10	0.20
(A-1-2)27bdd-1[5]	8	Valley fill	--	7	----
(A-1-2)27bdd-1	18	----do----	--	--	----
Average Kelvin	115	------------	43	22	2.50
Average Valley fill	76	------------	42	23	2.51
Pinecrest sub-basin					
(A-1-2)27bac-2	105	Valley fill	48	20	2.00
(A-1-2)27bac-1	90	Preuss	3	8	----
(A-1-2)16dcd-1	91	Ankareh	69	35	1.75
(A-1-2)16dac-1[4]	196	Valley fill	134	--	----

[1] Water level observation well
[2] Gamma-ray log well
[3] Temperature observation well
[4] Chemical analyses well
[5] Replacement wells of wells with the same well number

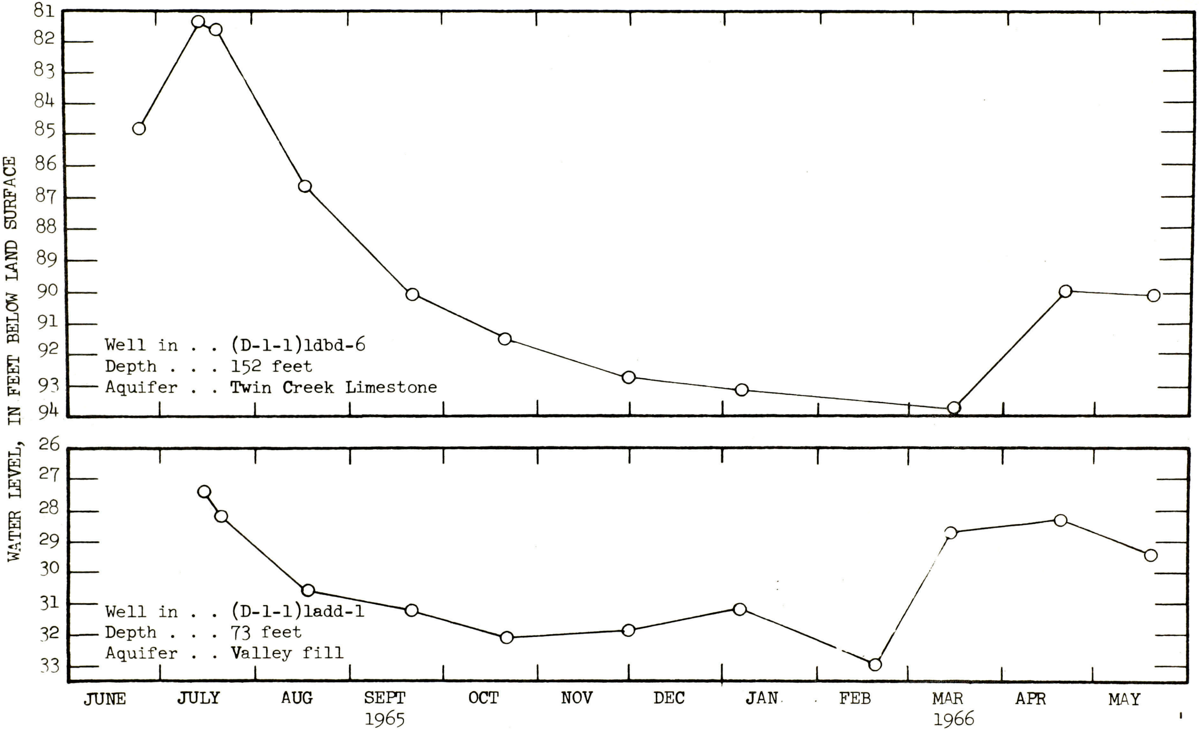


Figure 16.--Hydrographs of water levels in 8 observation wells in Emigration Canyon.

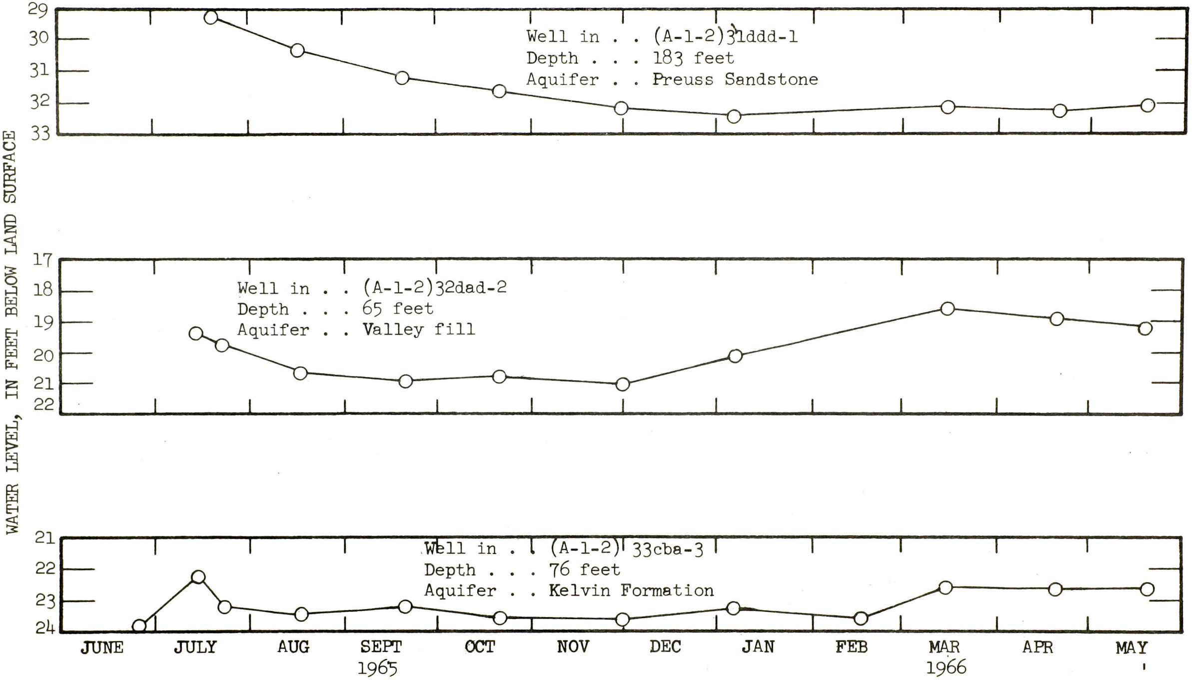


Figure 16.--Hydrographs of water levels in 8 observation wells in Emigration Canyon--Continued

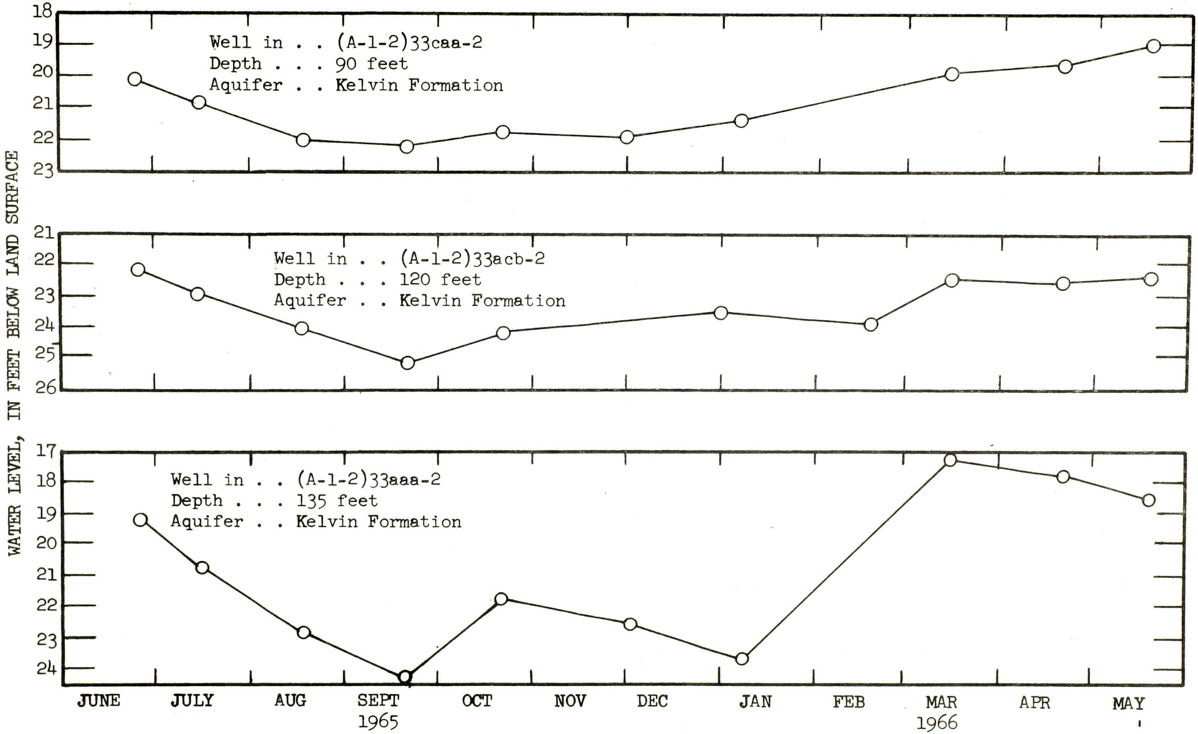


Figure 16.--Hydrographs of water levels in 8 observation wells in Emigration Canyon--Continued

three wells lower in the canyon over the period of observation. The deepest water levels were observed in the five wells in the Kelvin sub-district in the months of August, September, October, and November; the deepest water levels were observed in the lower three wells in October, January, and February.

Users of wells in the Twin Creek sub-district have stated that water levels reach their deepest level each year in the months of January and February. They have also stated that the water levels reached an all-time low during the months of January and February, 1962. Water levels dropped to an elevation below the bottom of many of the shallow wells and below the impellers of many of the other wells in that year. Many of the home owners had to haul water for domestic use during this time. The winter of 1961-62 followed the water year of 1961 when the flow of the stream was less than any other water year of record (fig. 11 and table 1).

Aquifer material encountered.--Some of the wells yield water that is produced from aquifers within the alluvial material, and a few of the wells yield water from both the alluvial material and the bedrock formations. Most commonly, however, the water that is yielded to the wells in the canyon is from the bedrock formations alone (table 6).

To determine the nature of the material in which each well was constructed, the well driller's log was studied in detail and graphically plotted for comparison and correlation with other logs. The wells in the canyon were constructed by 12 separate drilling contractors. The interpretation of the material encountered while drilling the well depends upon the individual well driller as well as the nomenclature used. During well construction many of the drillers encountered material that they were not accustomed to encountering. This is because most of their drilling experiences have been in the deep alluvial fills of the valleys in the Basin and Range physiographic province. The fact that one drilling company has constructed more than 70 per cent of the wells in the canyon was helpful in interpreting and correlating the logs.

The contact of the alluvial material and the bedrock formation was not obvious in many of the logs, and the author found it necessary to use his own judgment in locating this contact. Many times the drills would encounter large boulders in the alluvial material that could easily be confused with the bedrock formations. It also appears that the top few feet of bedrock is often weathered, softened, and fractured so that it was not as resistant as it once was.

Gamma-ray logs were run on six wells in an effort to learn more of the nature of the material penetrated. The gamma-ray probe placed in the wells measures the gamma rays naturally emitted by the material around the well casing. The radioactive level of the material is very low; therefore, the gamma-ray probe must be very sensitive. The gamma-ray logs were useful in the identification of the alluvium-bedrock contact. The locations of the well sites where the gamma-ray logs were run are shown in figure 14, and the gamma-ray logs, together with information from the corresponding well drillers' logs, are shown in figure 17.

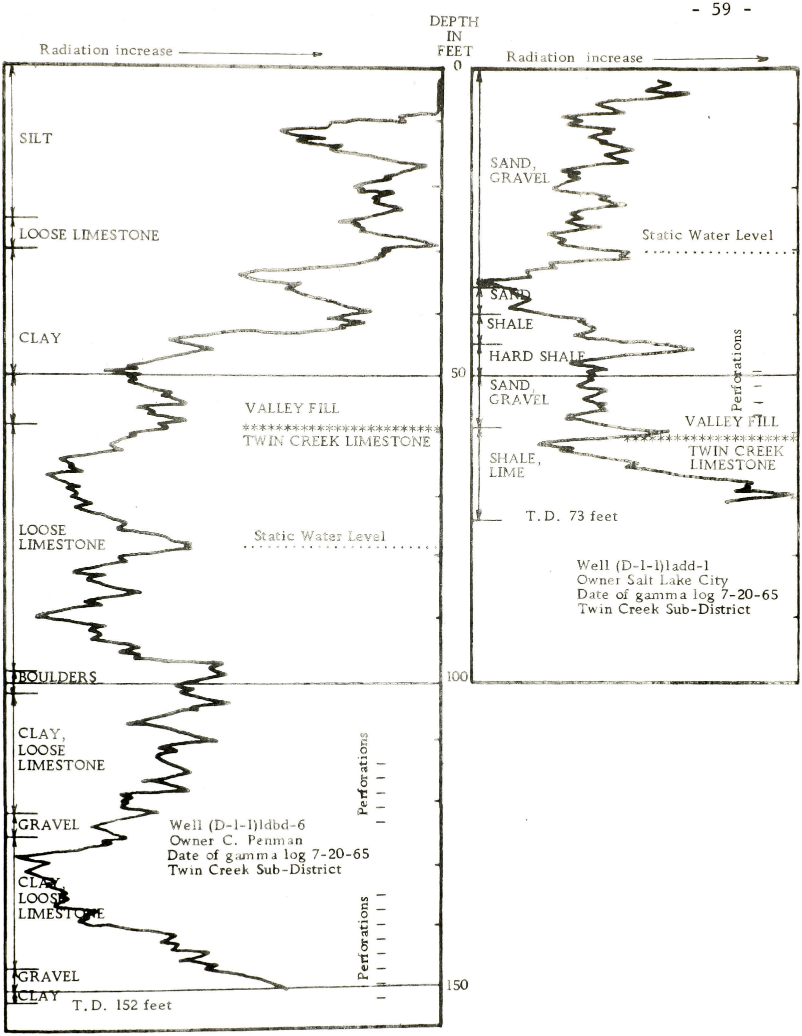


Figure 17.--Gamma ray logs and well driller's information from 6 wells.

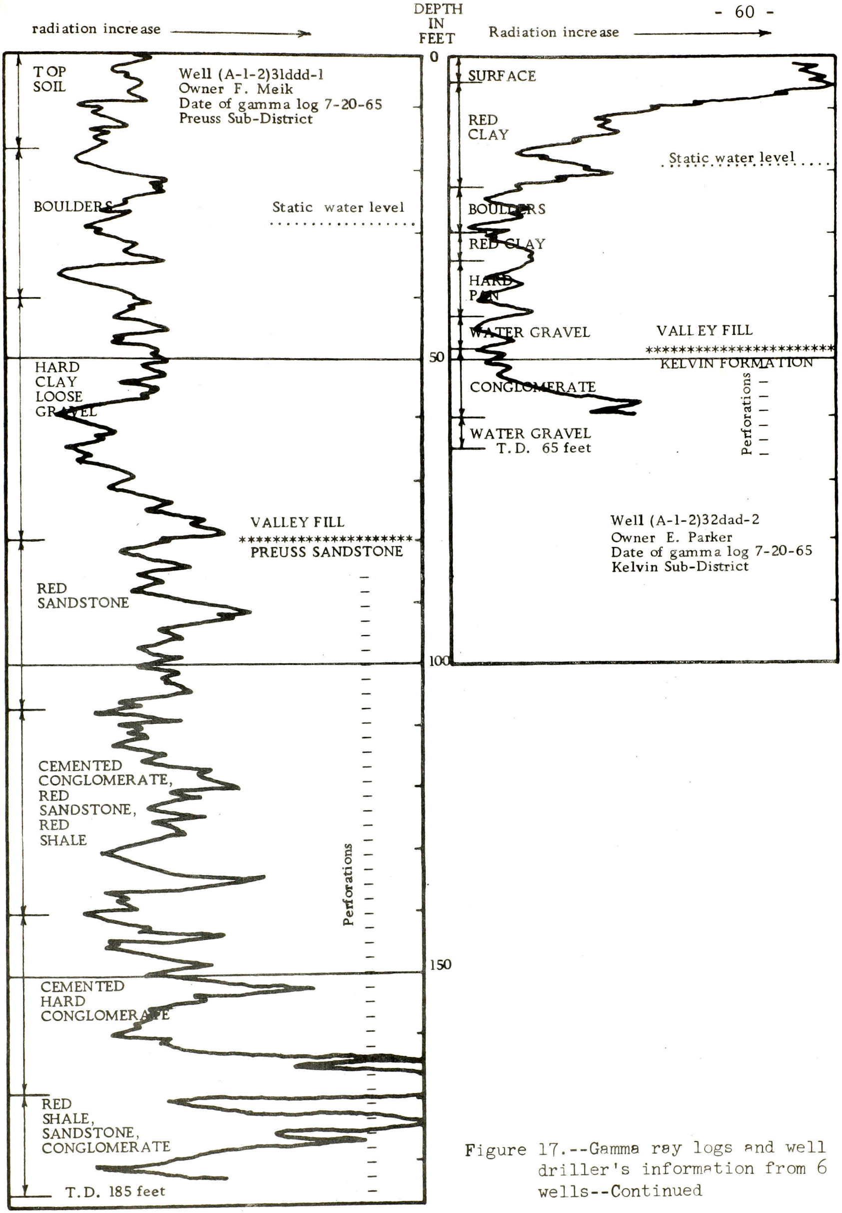


Figure 17.--Gamma ray logs and well driller's information from 6 wells--Continued

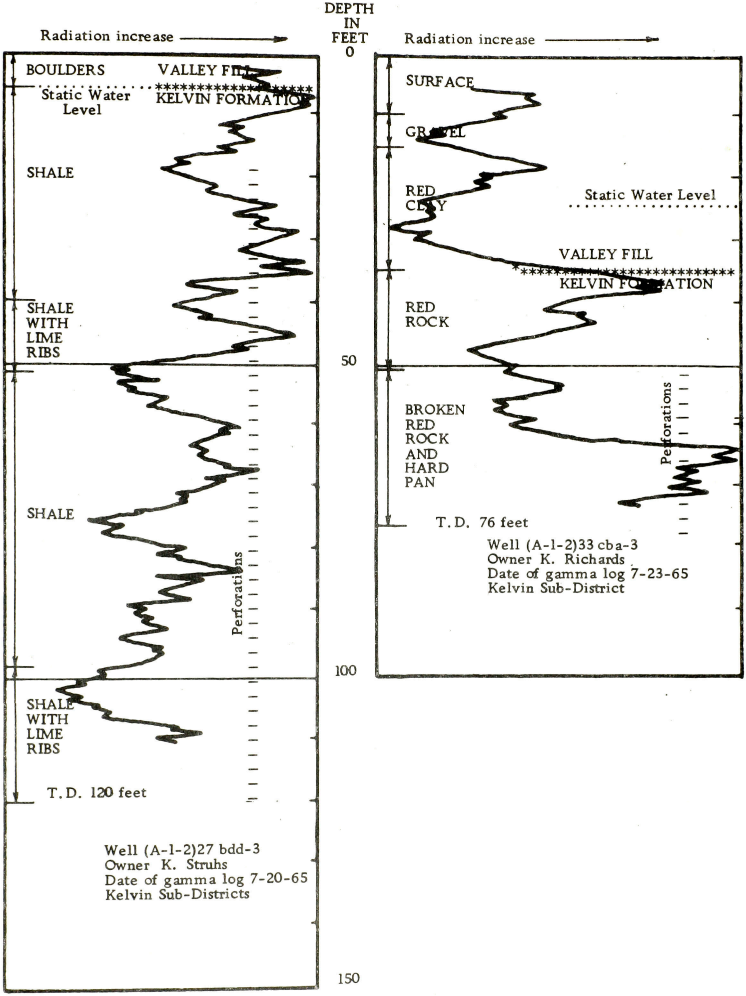


Figure 17.--Gamma ray logs and well driller's information from 6 wells--Continued

Aquifers in the canyon do not yield water readily to the wells, and few of the wells in the canyon collect water fast enough to prevent excessive drawdown of the water levels when more than a few gallons a minute are pumped. The specific capacity of a well is the number of gallons of water per minute that a well can produce for each foot of drawdown.

From the drillers' logs, the specific capacities of the wells in the canyon were calculated, and the values are given in table 6. In most of the well drillers' reports, the rate of flow of the well during a pump or bailing test is given. The amount the water levels were lowered during the test is usually given. If the above-indicated information is not given in the drillers' reports, specific capacities could not be calculated for the wells. Information given in the drillers' logs is not comparable to the quality of data collected under a controlled pump test when the water levels are precisely measured, and the well is pumped at a known rate for a prolonged period of time. However, despite the apparent weaknesses in the available data, the calculated specific capacities are of value. Specific capacities as calculated for the wells in the area range from 20 gpm per foot of drawdown to 0.06 gpm per foot of drawdown and average 2.70 gpm per foot of drawdown. These values are very low when compared with wells in the alluvial material west of the study area. Specific capacities of the wells in the alluvial material in Jordan Valley adjacent to the study area average 42 gpm per foot of drawdown (Marine and Price, 1964).

The specific capacity of a well is related to the ability of the aquifer to transmit water, or in other words to the aquifer's transmissibility. The specific capacity of a well is also dependent on the construction and development of the well. This includes the diameter of the well, the type, size, and amount of the perforations, and the type and amount of development the well has had. Despite the influences of the well construction, the specific capacity is useful in estimating the transmissibility of an aquifer. It is also useful in estimating the relative efficiency of wells.

Chemical and Biological Water Quality and Water Temperature

Chemical analyses of the water from one spring and nine wells (table 2) indicate that the quality of the ground water in the canyon ranges from water suitable for culinary use to water completely unsuitable for culinary use. The spring and all but two of the wells sampled produce water of a calcium bicarbonate type that is satisfactory for culinary purposes. Water from the other two wells is of two distinctly different types, high in dissolved solids and not suitable for culinary supply.

The ground water is used in the canyon almost exclusively for culinary purposes. Because of this, the standards of the U. S. Public Health Service for drinking water were consulted to determine the suitability of the water. The U. S. Public Health Service in its publication entitled, "Drinking Water Standards" (1962), states that it is desirable for drinking water to contain less than 250 ppm (parts per million) chloride, 125 ppm magnesium, 250 ppm sulfate, and 500 ppm total dissolved solids. The Health Service recommends that drinking water not contain more than 500 ppm chloride, 250 ppm magnesium, 500 ppm sulfate, 44 ppm nitrate, and 1,000 ppm total dissolved solids.

All the underground sources contained water significantly under the desirable limit of chloride concentration except the 120 foot deep well numbered (A-1-2)27bdd-3. Water from this well contains an excessive amount of chloride--9,310 ppm--and is not fit for human consumption. All of the underground sources sampled contain water within the desirable limit of magnesium concentration except the aforementioned well, (A-1-2)27bdd-3, which contains an excessive amount of magnesium--526 ppm. All but two of the underground sources sampled contain water below the desirable limit of sulfate concentration. Water from the aforementioned well, (A-1-2)27bdd-3, contained 444 ppm sulfate. Water from well (A-1-2)16dac-1, the highest well in the canyon, contains an excessive amount of sulfate, 1,360 ppm, and drinking this water would have a strong laxative effect for someone not accustomed to this concentration of sulfate in his drinking water. None of the sources sampled contained water with a concentration of nitrate in amounts near the limit set by the Health Service.

Only three of the sources sampled contained water with total dissolved solids less than the desirable 500 ppm. An additional five sources sampled contained water with more than 500 ppm, but less than 1,000 ppm total dissolved solids. Water from well (A-1-2)16dac-1 contained 2,290 ppm total dissolved solids, and water from well (A-1-2)27bdd-3 (120 feet deep) contained 16,900 ppm total dissolved solids. Because of the large amounts of total dissolved solids present in both of these wells, neither should be used for culinary purposes.

Waters that contain $CaCO_3$ (hardness) in concentrations of less than 60 ppm are classified by the Public Health Service pamphlet as soft water; concentrations of more than 60 ppm, but less than 120 ppm, are classified as moderately hard; concentrations of more than 120 ppm, but less than 180 ppm are classified as hard, and concentrations of over 180 ppm are very hard. All the waters sampled are classified as very hard, and the water from wells (A-1-2)27bdd-3 and (A-1-2)16dac-1 contained $CaCO_3$ in concentrations of 4,330 ppm and 1,540 ppm respectively. The primary objections to hard water when used for culinary supply are that more soap is required in washing, and deposits of minerals accumulate in pipes, in water heaters, and on plumbing fixtures.

Several residents of the canyon with wells in the Pinecrest and Kelvin sub-districts have complained to the author about the brown or orange color of water pumped from their wells and the bitter taste that such water has. Water that is high in iron will turn orange to orange brown when it is exposed to the air. Because of this characteristic, water high in iron will stain plumbing fixtures and discolor clothes washed in it. The water samples collected were not analyzed for iron content, but it is apparent that some of the wells produce water that contains an excessive amount of iron. High iron content of the water appears to be mostly limited to the upper part of the canyon since it has not been brought to the author's attention by residents living in the lower Preuss or Twin Creek sub-districts.

The reasons for the high concentration of dissolved solids in water taken from two wells require special consideration. This will be treated later in the text in the discussion of the sub-districts in which the wells are located.

Some of the ground water in the canyon used for culinary purposes has been contaminated by coliform bacteria. Health authorities feel that the presence of any coliform bacteria in culinary water renders it unfit for human consumption. If a sample is free from coliform bacteria, it is referred to as a negative sample. If coliform bacteria are found in the sample, it is referred to as a positive sample. At the request of the water user, the Salt Lake County Board of Health will sample culinary water and test it for bacteria. The department has reported to the writer that of 68 samples collected and analyzed from 1960 to the present time, 24 were positive and 44 were negative. Caution should be taken in using these figures, because they do not represent a random sampling of the culinary supplies. In many cases the samples were collected and analyzed at the request of the home owner because he had reason to suspect contamination. In addition, these figures represent in some cases more than one sample from a single source taken at various times to determine if a once-contaminated supply had become free from bacteria.

Of the 68 samples, 12 are from springs. Of these spring samples, 6 were positive and 6 were negative. Although it cannot be determined directly from the data supplied by the county, additional information available to the author indicates that of the remaining 56 samples, about 28 were from shallower wells and about 28 were from deeper wells. Of the 28 samples from the shallow wells (wells less than 40 feet deep), 11 were positive and 17 were negative. Of the 28 samples from deep wells, 7 were positive and 21 were negative.

Observations of water temperature were made in three deeper wells on a periodic basis during the study (table 3 and fig. 14), and several other water temperatures were observed in additional wells during the gamma-ray logging operations. The temperatures of underground water ranged from 46° to 57°. Two of the wells observed on a regular basis are in the Twin Creek sub-district. In well (D-1-1)1cdc-2 the temperature ranged from 57° to 54° with the lowest temperature being observed in September. In well (D-1-1)1dbd-4 the temperature ranged from 49° to 53°, and the lowest temperatures were in June and February. The third well is higher in elevation than the first two and is located in the Kelvin sub-district. The temperatures in well (A-1-2)33aaa-2 ranged from 46° to 50° with the lowest temperature observed in February. The temperature in each of the three wells did not fluctuate more than four degrees. The temperature of the water in shallower wells was not observed.

The monthly average temperatures of the water from Emigration Tunnel Springs from 1963 to 1965 range from 50° to 56° and average about 53° (table 5). Limited data would indicate that the water from Wagner Springs is near the same temperature.

The observed water temperatures from underground sources do not show a fluctuation corresponding with the change in seasons or the annual change in the temperatures of the water in the creek. It might be expected that the temperature of the ground water from deep sources would be near the average annual temperature in the area. From the limited data available this appears to be true. Information from the weather observation station in Parleys Canyon suggests that the central part of the study area will have an average annual temperature near 48°. This is within one degree of the average temperature observed in well (D-1-2)33aaa-2 in the central part of the study area. The ground-water temperatures observed lower in the canyon are a few degrees higher and are near the average annual temperature observed by the Mountain Fuel Supply Company at their pump station near the mouth of the canyon. It is reported that the average annual temperature at this station is about 51° (Leo Wilde, personal communication, 1966). The average temperature of the water in well (D-1-1)1cdc-2 is about 55°, only four degrees above the average annual temperature at the Mountain Fuel station. The average temperature of the water in well (D-1-1)1dbd-4 is about 50°, only one degree lower than the average temperature at the station. The average temperature of the water from Emigration Tunnel Springs is just two degrees above the average temperature at the Mountain Fuel Supply station.

Total Ground-Water Discharge from Wells

From data available to the author, it is estimated that about 100 acre-feet of water is pumped annually from the ground-water sub-districts in Emigration Canyon. Of this 100 acre-feet, about 70 acre-feet is pumped for culinary purposes and 30 acre-feet for irrigation purposes. This is less than an acre-foot per well each year and is less than one-fortieth of the annual average flow of the creek past the stream gage.

There are about 120 drilled wells in the canyon, as stated in an earlier section of the report. It is estimated that about 70 per cent of these wells are used by full-time residents, and the remaining 30 per cent of the wells are pumped to supply water for only portions of the year.

The State Engineer's Office has determined, in connection with its adjudication procedures, that a family requires .73 acre-feet of water per year for culinary use. Summer homes in the canyon would require about half that amount, or .36 acre-feet of water.

Although some of the homes have sizable lawns and gardens, many have only small irrigated areas, and several have none. It would appear to the author, without a detailed study, that the average irrigated acreage around each home in the canyon would not be more than one-eighth of an acre. With the supplemental irrigation from surface sources that takes place in the canyon on some of the lawns, it is doubtful that the irrigated acreage would require on an average of more than 2 acre-feet of water per acre from ground-water sources.

The ground water withdrawn for domestic use is not wholly consumed; probably more than 50 per cent of the 100 acre-feet pumped annually from the ground is returned to the hydrologic system in the canyon after its use.

HYDROLOGY OF THE GROUND-WATER SUB-DISTRICTS

Twin Creek Sub-District

Logs of 45 wells in the Twin Creek sub-district are on file with the Utah State Engineer's Office (fig. 7). Approximately one-third of the wells produce water from the unconsolidated valley fill, and two-thirds of the wells are drilled through the valley fill and produce water from the underlying Twin Creek Limestone.

Material encountered during the drilling of wells into the Twin Creek Limestone has been described by the well drillers in various terms. Most commonly used terms are: bedrock, broken bedrock, limestone, broken limestone, shale, limy shale, solid lime rock, and red rock. The water produced by the wells most frequently comes from the materials termed broken bedrock or broken limestone. Alluvial material above the Twin Creek Limestone is a mixture of clay, gravel, and boulders. From the well logs, it would appear that the material is poorly sorted, and that the various horizons cannot be correlated from one well to another.

Gamma-ray logs were run on two wells in the sub-district. At well (D-1-1)1dbd-6 the alluvial material is generally more radioactive than the Twin Creek Limestone (fig. 14 and fig. 17). The alluvial material in this case was silt and clay, and the bedrock formation appeared to be predominantly a limestone. At well (D-1-1)1add-1 the alluvial material is less radioactive than the Twin Creek Limestone (fig. 14 and fig. 17). The alluvial material around this well is gravel with some clay, and the bedrock formation appears to be shale and limestone.

The depths of the wells in the sub-district range from 58 to 250 feet. The average depth of the wells producing water from the Twin Creek Limestone is 122 feet, and the average depth of the wells producing water from the valley fill is 85 feet (table 6).

The well drillers' reports indicate that when the wells were test pumped, both the wells in the Twin Creek Limestone and the valley fill produced an average of 26 gpm. From the information in the well drillers' reports concerning the production of the wells, the static water levels, and the water-level drawdowns during pumping, it was calculated that the specific capacities of the wells in the valley fill are higher than the specific capacities of the wells in the Twin Creek Limestone. The specific capacities of the wells producing water from the valley fill averaged 4.36 gpm per foot of drawdown, while the specific capacities of the wells producing water from the Twin Creek Limestone averaged 2.84 gpm per foot of drawdown.

In almost every well within the sub-district, the water rose in the well casing above the level of the highest perforation in the well casing. This indicates that the water in the aquifers is under artesian pressure. The water rose on an average of 15 feet above the perforations in the wells producing water from the valley fill, and it rose 21 feet in the wells producing water from the Twin Creek Limestone. The depth of the water levels reported in the wells ranged from 18 to

207 feet, but most of the water levels reported were from 40 to 100 feet below land surface.

The water levels in the sub-district reach a low late in the winter season and a high in the summer season (fig. 16). The water level in observation well (D-1-1)1dbd-6 dropped about 13 feet from July 1965 to March 1966. This water-level drop is the greatest observed by the author in the canyon during the study. The annual low of the water levels in the Twin Creek sub-district is later in the year by two or three months than it is in the Kelvin sub-district. The low and high ground-water levels follow the periods of minimum and maximum stream flow by a short period.

The ground water in the Twin Creek sub-district appears to be of a satisfactory chemical quality for culinary use. The water is very hard, however, and the use of water softeners in the homes is common. The quality of the water in well (D-1-1)cdc-2 and the quality of the water from Emigration Tunnel Springs is very similar (table 2). The water from these two sources contains slightly more sulfate than most of the ground water in the canyon; however, the water is very similar to most of the water found in the other sub-districts.

The ground-water temperatures are generally in the low fifties and do not vary more than a few degrees. As pointed out in an earlier section of the report, the temperature of the ground water is near the average annual temperature in the Twin Creek sub-district.

The records of the Salt Lake County Board of Health indicate that 13 samples of water from deep ground-water sources have been analyzed for coliform bacteria. It is reported that in 12 of the samples, coliform bacteria were not present, and in 1 sample, the bacteria were present. This single, contaminated sample does not indicate that the contamination of the water by coliform bacteria was necessarily coming from deep ground-water sources. Bacteria could have been present on the well casing, on the plumbing, or the bacteria could have been introduced at the time of sampling.

Two samples of water from shallow ground-water sources (wells less than 40 feet deep) in this sub-district have been analyzed for coliform bacteria. One was free from bacteria, and the other one was contaminated. Contamination of the shallow ground water could have been from either the stream or from nearby septic tanks.

Preuss Sub-District

Logs of 12 wells in the Preuss sub-district are on file with the Utah State Engineer's Office (fig. 7). Only 1 of these wells produces water solely from the valley fill. Another well produces water from both the valley fill and the Preuss Sandstone, and 10 of the wells produce water solely from the Preuss Sandstone.

Material encountered by the drilling of wells into the Preuss Sandstone has been described by the well drillers in various terms. The most commonly used terms are: bedrock, broken bedrock, red rock, very hard shale, red shale, sandstone, broken sandstone, red sandstone, and red conglomerate. Water encountered and produced by the wells most frequently comes from the materials termed broken bedrock, sandstone, and broken sandstone.

A gamma-ray log was run on one well in the sub-district, (A-1-2)31ddd-1. The alluvial material was less radioactive than the Preuss Sandstone (fig. 14 and fig. 17). The alluvial material was mostly boulders and conglomerates mixed with clay. The bedrock was predominantly sandstones and conglomerates with streaks of clay. The material in the well was more radioactive than any in the other wells logged in the canyon. For this reason, the sensitivity of the device recording the level of radioactivity had to be turned to a lower setting during the logging of this well. Direct comparison of the magnitude of the fluctuations of the radioactive levels recorded from this well with those of other wells as recorded in figure 17 would be misleading.

The depths of the wells in the sub-district range from 60 to 183 feet. The average depth of the wells producing water from Preuss Sandstone is 94 feet, and the depth of the single well producing water from the valley fill is 81 feet (table 6).

The well drillers' reports indicate that when the wells were test pumped by the drillers, the wells in the Preuss Sandstone produced an average of 22 gpm. From the well drillers' reports, it was calculated that the specific capacities of the wells in the Preuss Sandstone averaged 2.02 gpm per foot of drawdown.

The water rose above the perforations in all but one of the wells. This indicated that the water in the aquifers is under artesian pressure. The water rose on an average of 28 feet above the perforations in the well casings of the wells producing water from the Preuss

Sandstone. The depths of the static water levels reported in the wells within the sub-district ranged from 3 feet to 35 feet below the land surface.

From the water-level measurement made in the single observation well within the sub-district, it appears that the water levels reach a high in midsummer and a low in midwinter (fig. 16). This period of low and high water levels is similar to that observed in the Twin Creek sub-district but is later than the minimum and maximum stream flow by a short period.

The ground water in the sub-district was not sampled and analyzed for chemical quality. The absence of unfavorable comments by the residents of the area leads to the assumption that the water is of satisfactory quality for domestic use.

The records of the Salt Lake County Board of Health show that six samples of water from shallow ground-water sources have been analyzed for coliform bacteria. It was reported that in two of the samples, coliform bacteria were present, and in four samples, they were not. Only one sample was collected and analyzed for coliform bacteria from deep sources. This sample was negative.

Kelvin Sub-District

About one-half of all the wells drilled in Emigration Canyon are in the Kelvin sub-district. Logs of 65 wells in the Kelvin sub-district are on file with the Utah State Engineer's Office (fig. 7).

About one-third of these wells produce water from the unconsolidated valley fill, and two-thirds of the wells produce water from the underlying Kelvin Formation.

The material encountered in drilling the wells into the Kelvin Formation has been described by the well drillers by many terms. The most commonly used terms are: bedrock, broken bedrock, conglomerate, shale, hard shale, sandstone, broken sandstone, red rock, broken red rock, limestone, broken limestone, and cobble formation. Water encountered and produced by the wells most frequently comes from the materials termed broken bedrock, conglomerate, broken sandstone, broken red rock, and broken limestone.

Alluvial valley fill material above the Kelvin Formation appears to be very similar to the alluvial material present in the Preuss and Twin Creek sub-districts. The material is poorly sorted and is composed of clay, gravel, and boulders. The valley fill material in this sub-district is red to orange in color and appears to have a higher percentage of cobbles and boulders than the alluvial material in the other sub-districts.

Gamma-ray logs were run on three wells in the sub-district, and there appears to be little or no correlation in the radioactivity in the three wells (fig. 14 and fig. 17). In well (A-1-2)32dad-2, the Kelvin Formation is more radioactive than the deep valley-fill sediments, but noticeably less radioactive than the near-surface valley fill material. In well (A-1-2)33cba-3 the Kelvin Formation is more radioactive than the overlying alluvial material. In well (A-1-2)27bdd-3, which is

120 feet deep, the alluvial material is only a few feet thick, and the underlying Kelvin Formation becomes less radioactive with depth. This well yields water that is poorer in chemical quality than any other water analyzed in the canyon.

The depths of the wells in the sub-district range from 8 feet to 405 feet and average 101 feet deep (table 6). The average depth of the wells producing water from the Kelvin Formation is 115 feet, and the average depth of wells producing water from the valley fill is 76 feet.

When the wells were test pumped by the well drillers, the average yield was almost the same for wells producing water from the Kelvin Formation and from the valley fill. The average production from wells in the Kelvin Formation was 22 gpm, and the average production from the valley fill wells was 23 gpm. From the information in the well drillers' reports, it was calculated that the specific capacities of the wells in the valley fill and in the Kelvin Formation are the same--2.5 gpm per foot of drawdown.

In every well within the sub-district, the water rose in the well casing above the level that water was allowed to enter the well. This indicates that the water in the aquifers is under artesian pressure. Water rose on an average of 42 feet above the perforations in the well casings of the wells that produced water from the valley fill, and 43 feet in the well casings of wells that produced water from the Kelvin Formation. On the average, water in the sub-district is under greater artesian pressure than the water in the Preuss or Twin Creek sub-districts.

In one well, a rise of 119 feet above the perforations was reported. The depths of the water levels in the wells within the sub-district ranged from 2 to 37 feet, and the average level was only 18 feet below the land surface.

The water levels in the sub-district as observed in five wells reached lows in the months of September and November (fig. 16). These ground-water lows were at an earlier date than was recorded in the lower sub-districts. The water-level fluctuations in the observation wells in the sub-district varied from a maximum of about 7 feet in well (A-1-2)33aaa-2 to a minimum of about 1.5 feet in well (A-1-2)33cba-3 during the period of study.

Samples of water from five wells in the sub-district were collected and analyzed for chemical quality. The quality of the water from four of the wells is satisfactory for domestic use and is a calcium bicarbonate type similar to the water in the Twin Creek sub-district. The water is very hard, and the use of water softeners is common in the area. Several of the home owners also commented that the water from some of the wells contained a high enough concentration of iron to leave bothersome orange stains on fixtures and laundry.

Well (A-1-2)27bdd-3 yields water of a quality completely unrelated to any other waters analyzed. The water from this 120 foot deep well is a sodium chloride type, and the amount of total dissolved solids is very high. This water is completely unfit for domestic use. Two wells within 150 feet of each other were sampled at this location (table 2). The well that yields water of very poor quality is 120 feet deep and is perforated from 20 to 120 feet. The other well is 405 feet deep and is thought to be perforated at about 125 feet. This deeper well yields water of chemical quality very similar to waters sampled in all the wells below this location in the canyon. It is of a calcium bicarbonate type and is suitable for domestic use. The two wells were constructed by the same drilling company, and although they are within 150 feet of each other, the logs of the two wells cannot be closely correlated. The predominant material encountered in both wells was shale.

The well casing of the 120 foot deep well is cut off 4 feet below the land surface. The artesian pressure in the aquifer is great enough to cause the water to flow, very slowly, over the top of the well casing. The rate of flow is so slow that this highly mineralized water seeps into the ground around the well casing. This is the only flowing well in the canyon that the author has observed.

In an effort to determine the source of the poor-quality water, a gamma-ray log of the well was run. In addition, logs were run to determine the temperature and resistivity of the water in the well. The gamma-ray log indicates that the radioactivity of the material surrounding the well decreases with depth (fig. 17). No unusual fluctuations in the radioactivity were observed, and the gamma-ray log gave no insight as to the source of the poor-quality water.

The temperature of the water as it flowed over the top of the well casing was 58.5° on July 20, 1965. This was also the temperature of the creek on this particular day. The creek flows only 50 feet from the well. The water temperature decreased from the 58.5° at the top of the casing to 45° at 28 feet below the land surface. From 28 feet to 114 feet, which was as deep as any of the probes could enter the well, the temperature remained quite constant, increasing only one degree to 46° in 86 feet. The temperature probe also failed to identify the source of poor-quality water. The warming of the water near the top of the well could be a result of warmer, shallow ground water surrounding and warming the upper part of the well casing. The water flowing up the well appears to be moving slowly enough to allow this. The shallow ground water and the surface stream could be closely connected. This close relationship of waters would account for the identical temperatures of the water in the creek and the water at the top of the well.

The resistivity log clearly demonstrates that the quality of the water in the well casing does not vary from top to bottom. This indicates that if water is entering the well casing at locations other than at or near the bottom of the well, it is of the same quality as the water entering the well at the bottom. It appears likely that most of the water enters the well at or near the bottom of the casing.

The well driller has recorded in his log that the material in the bottom 22 feet of the well is a shale with "lime ribs". The surface location of the well is near the base of the upper member of the Kelvin Formation. The beds are dipping steeply to the southeast. The vertical well casing would have a component greater along the dip of the beds than through the beds. However, it is possible that the well does penetrate through the upper member into the Parleys Member of the Kelvin Formation.

It is not readily apparent where the source of poor-quality water is, nor is it apparent where the source of sodium chloride might be. The author feels that the most likely source of the sodium chloride is in the sediments of the Parleys Member. The lithology of the Parleys Member indicates that during the period when the member was deposited, the area was inundated. There was an opportunity for small ponds to be isolated and evaporated, leaving behind isolated evaporite deposits. The well may have been drilled through the upper member and directly into the Parleys Member and into an isolated evaporite deposit. It is also possible that the well is completely in the upper member, but is encountering upward-moving water that has come in contact with an isolated evaporite deposit in the Parleys Member or the older Preuss Sandstone. The net result would be the same, the water would be high in sodium chloride. The fact that the deeper well 150 feet away did not encounter poor-quality water can be explained by the limited extent of the evaporite deposits.

It is apparent that the occurrence of sodium chloride water in the canyon is not widespread. If this were not the case, the very high concentration of dissolved solids in the sodium chloride water from well (A-1-2)27bdd-3 would affect the chemical quality of the water in the nearby well and other wells downstream.

Well (A-1-2)33aaa-2 was used as a temperature observation well in the sub-district, and it yielded water that varied in temperature from 46° to 50° during the period of study (table 3). Although the temperatures were very different from those observed in the creek, there was an indication of annual variation of water temperature in the well water that corresponded in time with the change in the stream temperature. Of the three temperature observation wells in the study area, only the readings from this well suggest this relationship.

The records of the Salt Lake County Board of Health show that 14 samples of water from deep ground-water sources have been analyzed for coliform bacteria from this sub-district. In 8 of the samples, coliform bacteria were not present, and in 6 of the samples, coliform bacteria were present. The 6 positive samples were collected from three wells. Two of the wells were newly constructed wells at the time of sampling. After these two wells had been pumped for a period of time, samples were collected and found to be free from coliform bacteria. The bacterial contamination may have been introduced during the drilling of the well, or it may have been present in the well casing or in the well plumbing. If this is the case, the water in the aquifer is not contaminated.

The records of the health department show that 18 samples were analyzed from shallow sources. Of these samples, 11 were negative, and 7 were positive. From the records available, it is impossible to determine if the contamination to the shallow ground water was from the installation of the diverting works or directly from the polluted stream and nearby septic tanks.

Pinecrest Sub-District

The Pinecrest sub-district is primarily a summer home area. For this reason, the homes are not as substantial, and the development of water systems is not as extensive or as elaborate as in the other sub-districts. Many summer homes are supplied with water from small springs or seeps, and some home owners haul water for their domestic use.

Logs of only four wells located within the Pinecrest sub-district are on file with the Utah State Engineer's Office (fig. 7). The depths of these four wells listed in sequence from the lowest elevation to the highest are: 105 feet, 90 feet, 91 feet, and 196 feet deep.

There are 10 geologic formations in the sub-district that dip steeply to the southeast. The two lower wells in the sub-district are constructed in an area where the alluvial material is underlain by Preuss Sandstone. The two higher wells in the sub-district are constructed in an area where the alluvial material is underlain by the Thaynes Limestone. The land surface gradient and the gradient of the water table are much steeper in this sub-district than in any of the other lower sub-districts. Less is known about the ground-water hydrology of the area than any of the other sub-districts. It is more difficult to predict what hydrologic conditions may be at any given location.

A sample of water was collected from one well in the sub-district and analyzed for chemical content. This well (A-1-2)16dac-1 is the highest well in the canyon (table 2). It is 196 feet deep. At this location, the author anticipated that a well of this depth would have gone through the alluvial material and into the underlying Thaynes Limestone. However, the report of the well driller indicates that only alluvial material was encountered. The water sample from the well was high in total dissolved solids and was a calcium sulfate type water, distinct in chemical type from any other water sampled in the canyon. The water contained 1,360 ppm sulfate, which is well over the limit of 500 ppm recommended by the Public Health Service for drinking water. Drinking this water by someone not accustomed to it would produce a strong laxative effect. The quality of the water suggests that the water comes in contact with beds or deposits of gypsum. Water of this type is not encountered in other wells sampled in the canyon or in the samples taken from the stream. Because of the limited occurrence of water of this type, it is felt that the source of the calcium sulfate is isolated.

The owner of this well told the writer that the well is pumped and used on a very limited basis, and when it is, the water is very high in iron content. Stains on the fixtures in the home verified this. It is possible that if the well were pumped for an extended period of time, the quality might improve.

Temperature observations were made on two occasions of the stream and a spring located in (A-1-2)16dc to see if a change in stream temperature might be reflected in the spring temperature. On both occasions, the stream temperature was 52°, and the spring temperature was 50°. Additional observations were desired as the stream temperature dropped later in the year. The spring was not accessible to the author, however, after the summer home was closed for the winter, and additional observations could not be made.

A search of the records of the Salt Lake County Board of Health did not show a single bacterial analysis from the sub-district. The stream above the summer home area is felt to be relatively free from bacterial contamination. The bacterial count in the stream just below the sub-district is consistently lower than the bacterial count at the other sampling points farther down the canyon. It is assumed that the opportunity for bacterial contamination to the domestic water supplies is not as great in the Pinecrest sub-district as in the other sub-districts.

INTERRELATIONSHIP OF SURFACE WATER AND GROUND WATER

Water Temperature

The temperature of the stream varies with the weather and the seasons. The highest stream temperatures are in July and August, and the lowest are in January and February. The annual range in temperatures of the creek is somewhere between 25 and 30 degrees. The water from each of the three observation wells varied only 3 to 5 degrees over the study period, and only one well showed a temperature fluctuation that even roughly corresponded to the change in seasons. The temperature of the ground water in the observation wells is very near the mean annual air temperature of the canyon. This general relationship also appears to be true of the temperatures of the ground water in the bedrock springs observed. The contribution of surface water to the ground water is far enough removed from the observation wells for the water temperatures to be modified, and in effect, averaged before the water travels through the aquifer to the wells.

Effects of the warmer ground-water contribution from observed and unobserved springs on the colder winter stream were noted. The water temperature of the stream at the gage near Hogle Zoo ({D-1-1}11bcc) was 8 degrees higher than the other temperature readings of the stream on January 6, 1966. This suggested a significant contribution of warmer ground water in the lower reaches of the canyon.

On February 18, 1966, additional observations were made of the temperature of the stream to determine if this were true. On that day, the surface of the stream was covered with ice and snow from high in the canyon to the point where the flow of Wagner Springs enters the main stream in sec. 11, T. 1 S., R. 1 E. Below the inflow of Wagner Springs, the stream was completely free of ice and snow. Temperature of the stream above Wagner Springs was barely above 32°. Water from Wagner Springs was 47° just before it reached the main stream; water from another spring in the immediate area was 46° just before entering the stream. The temperature of the water from each of these springs was lower at the measuring point than at the point where the water issued from the spring. This was because the air temperature on this day was about 32°, and the water ran some distance from the spring areas in an open, natural channel before the temperature observations were made.

Water flowing from Emigration Tunnel Springs, about 1,100 feet upstream from the inflow of Wagner Springs, was 54° on the same day. The temperature of the stream about 1,800 feet downstream from the inflow of Wagner Springs was 43°; the stream at the gage about 3,000 feet below the inflow had cooled to 40°.

These temperature observations might have been anticipated in view of the results of the seepage run discussed earlier. It appeared to the author that on the day of the temperature measurements the stream was gaining in volume below Wagner Springs. This could be accounted for by additional unobserved ground-water contributions.

Chemical and Biological Water Quality

The chemical quality of the water from Emigration Creek, Emigration Tunnel Springs, and all but two of the wells sampled is very similar. The waters from the two wells that are the exception are of two distinctly different types and can be accounted for by isolated geologic conditions. Except for these two wells, the water is all a calcium bicarbonate type. The chemical quality of the ground water and surface water does not change appreciably in chemical type from high in the canyon to its mouth. The water also does not pick up a significant amount of total dissolved solids as it moves down the canyon.

The water quality suggests that the surface waters and the ground waters are from the same source. This interrelationship between the surface and ground waters is further emphasized by the fact that the ground water does not take on a significantly greater amount of dissolved solids as it moves through the earth material in Emigration Canyon. In most areas of Utah, the ground water contains significantly more dissolved solids than the surface water. This is because the water moving through the earth comes in contact with the earth materials for long periods of time and is able to dissolve some of the material and take it into solution. The slower the water movement or the longer it is in the ground, the more total dissolved solids the water is able to take in solution. The fact that the ground water in the canyon has not taken on additional dissolved solids is an indication that the ground water is not in contact with the earth material for a long period of time.

The surface stream is contaminated by coliform bacteria, and the source of the coliform bacteria is at or near the surface. Therefore, contamination of the ground water by coliform bacteria must be a result of the downward movement of surface water or water from septic tank discharge. The contamination could be, at least in part, the result of poor well construction and poor well location with respect to septic tanks. The sampling of the ground water in the canyon by the Salt Lake County Health Department indicates that a significant amount of the shallow ground water is contaminated with coliform bacteria. It is also possible that deeper ground water has been contaminated with coliform bacteria, but this has not been definitely established. It is as likely that the contamination of the deeper wells occurred during the drilling of the well from the well casing or plumbing or in the sample-collecting procedure. If some of the deeper ground water is contaminated, the contamination is not widespread. It appears that in Emigration Canyon the ground is an effective filter in preventing the downward movement of bacteria to much depth (below about 40 feet).

Results from the Seepage Run

The seepage run conducted by the U. S. Geological Survey demonstrated a definite interrelationship between the stream and the ground water. The observations, which were made by Al Horr in August 1965, have been discussed in an earlier portion of this report; the results are illustrated in figure 13.

In some reaches of the channel the surface stream is losing water and contributing it to the ground water, and in other reaches of the stream water is being added to the stream from subsurface sources. The major loss of surface water to the subsurface occurs in sec. 27, T. 1 N., R. 2 E. The water is lost to the stream channel as it passes over a very resistant, but highly jointed and fractured conglomerate in the Kelvin Formation. The reach of the stream that is gaining the most water from subsurface sources is in sec. 11, T. 1 S., R. 1 E. in the first mile above the stream gage near Hogle Zoo. In this reach of the stream all of the observed contributions to the stream were measured. In addition to the water measured, 1.234 cfs of water was being added to the stream from unobserved ground-water sources. The bedrock materials along this reach of the stream channel are mostly the more resistant, fractured and jointed beds in the Twin Creek Limestone.

Water-Level Changes and Artesian Pressures

The water levels in all the observation wells have an annual fluctuation that corresponds generally with the annual fluctuations of the stream flow. This indicates that the recharge to the stream and the ground water are directly related. The close dependence upon a surface source to maintain ground-water levels and artesian pressures as well as stream flow was illustrated in the winter of 1961-62. The stream ceased to flow in sections of the canyon, and the water levels dropped in some of the wells to a level where home owners were forced to haul water to their homes or to lower the pumping equipment in their wells.

During January 1966, water levels started to rise in five observation wells: (A-1-2)32dad-2, (A-1-2)33cba-2, (A-1-2)33caa-2, (A-1-2)33acb-2, and (D-1-1)1add-1 (fig. 5). The first part of January 1966 was unusually warm, and the stream was not frozen over for much of the month. During the latter part of January and the first part of February, temperatures were lower, and the stream was frozen over in much of the canyon. Because of deep snow, only three of the five wells could be located and water levels observed in February. In all three of the wells, the water-level rise that had been observed in January, had reversed, and the water levels declined. It is possible that the warm period in January released surface water that had been stored as ice, and made it available for ground-water recharge. During the latter part of January and the first part of February, a large part of the surface water was again placed in surface storage in the form of ice, and this water was not available for recharge to the underground reservoir. If this is a correct explanation for the small rise and decline of water levels during the early part of 1966, then the ground-water system is very sensitive to variations in the surface recharge.

In March and April of 1966, the air temperatures warmed and the snow and ice melted. This resulted in increased stream flow. Water levels also rose noticeably in all observation wells; in one well, (A-1-2)33aaa-2, this rise was about six feet.

POTENTIAL FOR FUTURE GROUND-WATER DEVELOPMENT

Present Water Rights

Established surface-water rights on Emigration Creek are for more water than the flow of the creek during most of each year. However, there is a short period of time during the spring season of many years when the high runoff is not fully appropriated, and a portion of the water is allowed to flow on toward the Jordan River. Most of the early-priority surface-water rights to irrigate lands within the canyon have been abandoned, or they have been acquired by parties who intend to use the water elsewhere. Some small tracts of land near the stream channel are irrigated by home owners who have placed small portable pumps in the stream. Most of these diversions are without water rights. In the upper part of the canyon, there is still an old pipeline that conveys water from high in the Pinecrest sub-district to irrigate lawns and gardens in the Pinecrest and Kelvin sub-districts. The users of this water claim an early-priority diligence water right.

Water rights that have been established after 1903 have all been established by filing an application with the State Engineer's Office. These rights are given a priority as of the date that the application was received in the State Engineer's Office. Almost all the rights under which the present home owners are diverting water from wells have a priority more recent than 1940, and the majority of the rights are more recent than 1950. A large percentage of these rights allow the owner to divert .015 cfs (7 gallons per minute) of water to be used for the domestic requirements of one family, and in some cases, for a small lawn and garden.

At the present time, there are new applications being received by the State Engineer's Office requesting permission to drill additional wells for use in new homes. Most of these request water to supply only one family, but some of these request the use of water for multiple-unit dwellings or as a supply for a small subdivision.

The Metropolitan Water District of Salt Lake City has filed an application with the State Engineer to appropriate 100 cfs and up to 3,500 acre-feet of water per year from Emigration Creek at a point 2,600 feet north and 2,200 feet east of the southwest corner of sec. 27, T. 1 N., R. 2 E. The district proposes to construct a tunnel 5,800 feet in length to convey the water from the Emigration Creek drainage into the Parleys Creek drainage. The water conveyed through this tunnel will be stored in the proposed Little Dell Reservoir. In the explanatory paragraph of the application, it is stated:

> "The purpose of this application is to divert surplus and flood water from Emigration Creek to the Little Dell Reservoir and to divert other water from Emigration Creek to said reservoir under applications as may be made by the Salt Lake City Corp. for changes in point of diversion, place and nature of use of water covered by water rights now owned by the City."

This application has been approved by the State Engineer, but there has been no development under it to date.

Effects of Additional Ground-Water Development

Interference between wells has not been a problem to date in the canyon. This is principally due to the fact that the pumping of any given well has not been at a high enough rate, and the period of pumping has not been prolonged enough to cause the individual cones of influence to extend out and significantly affect water levels in other wells. It is likely that many more small-diameter, one-family, domestic wells could be drilled and pumped without significantly interfering with the wells already constructed in the canyon.

If larger wells were constructed in areas where domestic well development has already taken place, and these wells produced large amounts of water, influence on the water levels in the domestic wells would be almost a certainty. It is probable that this influence could be measured directly, and it could be of significance to the domestic well owners. The very low specific capacities of the domestic wells indicate that the aquifers are not able to yield water readily to the wells. The drawdown of the water levels was several feet in some of the domestic wells when they were pumped at only a few gallons per minute.

It is doubtful that present well development has had the effect of interfering with surface water rights, at least in quantity. The total production of the wells in the canyon is less than one-fortieth the annual average stream flow. In addition, the domestic use of the water consumes only a small amount of the water diverted, and the water not consumed will return to the hydrologic system in the canyon and support the stream flow. The return flow of water diverted from the wells for domestic purposes will be greatly reduced if the Salt Lake County Board of Health requires all homes to use sealed vaults as a pollution control measure in place of septic tanks.

Most of the homes and lawns in the canyon occupy lands that were once fields irrigated from the stream. It is doubtful that as much water is consumed on lands now used as residential areas as was consumed when the lands were irrigated fields. Additional groundwater development and use in the future could interfere with the surface flow of the stream if this additional development and use were on lands that had not been irrigated in the past. The result would be a greater water consumption within the canyon and a lesser amount of water available to support the stream flow. To date most of the development has been along the stream channel. There are, however, many acres of land within the canyon suitable for home sites that are removed from the stream channel and have not as yet been developed as residential areas.

Effects of Additional Surface-Water Development

There is only a short period of time during the high spring runoff of most years that the stream is not fully appropriated. Therefore, any additional surface-water development under newly established rights would have to be limited to that very short period of time or the development would interfere with already established and senior surface rights. There is, however, the possibility that additional development of surface waters could take place by changing the point of diversion or the place or nature of use of already established rights.

It is likely that the diversion of additional water out of the stream channel, particularly during periods of low natural stream flow, would have the effect of lowering artesian pressures in the ground-water aquifers, thereby lowering the water levels in the wells that produce water from these aquifers. The surface flow performs another beneficial function in the canyon. That is one of diluting and transporting the contaminated waters away from the homes in the canyon. Any reduction in stream flow will increase the concentration of bacteria in the stream and increase the opportunity for bacteria to contaminate existing domestic water supplies. Not only would it increase the concentration, but it would also increase the time that the contamination would remain in the canyon before being carried by stream flow out of the area. It may well be that the high spring runoff has the beneficial effect of flushing out much of the canyon.

Most Favorable Areas for Future Ground-Water Development

Most of the flow of the stream and naturally occurring springs have been placed to beneficial use for a long period of time. Future development is mainly limited to additional ground-water development. It is doubtful that the ground water exists in sufficient quantities to allow the development of large volumes of water by wells, except on a limited basis in areas of the canyon other than near the stream channel. The Twin Creek sub-district, Preuss sub-district, and Kelvin sub-district below Burr Fork appear to have the best supply of ground water both from a quantity and quality standpoint. Development in these areas should be limited to small-diameter, domestic wells if influence on existing rights is to be avoided.

SUMMARY OF CONCLUSIONS

There are more than 120 drilled wells in Emigration Canyon. These wells represent the primary source of domestic water for the approximately 660 full- or part-time residents in the canyon.

Most of the wells produce water from three geologic formations--the Twin Creek Limestone, the Preuss Sandstone, and the Kelvin Formation. Some of the wells produce water from aquifers of the unconsolidated alluvial material in the valley fill above the bedrock formations. Water in all of the aquifers is also under artesian pressure, and the aquifers do not yield water readily to the wells.

Water in most of the aquifers is a calcium bicarbonate type and is suitable for use as a domestic supply even though it is chemically very hard. In isolated geologic conditions, the ground-water quality is very different chemically and is not of suitable quality for domestic use. The stream has been highly contaminated with coliform bacteria that are being discharged into the stream by effluence from septic tanks and livestock corrals. The coliform bacteria may have contaminated some of the shallow ground water either by seepage from the stream or by faulty well construction in combination with close proximity to domestic waste disposal facilities. The deeper ground water is generally free from coliform bacteria.

The surface water and the ground water are closely related. This was established by the similar quality of the water, the variation of artesian pressure in wells that corresponds to changes in stream flow, and the temperature changes in the stream in response to ground-water contribution. Deep ground-water aquifers are far enough removed from the surface recharge to average out the water temperature and make it nearly the same all year round (about 53° F.). A seepage run during the summer of 1965 established the fact that some reaches of the stream channel were gaining water from ground-water contributions and other reaches were losing water to the ground water.

Present ground-water development has not interfered with the surface flow of the stream or early-priority surface-water rights. To date there has not been significant mutual interference between the already drilled domestic wells. Additional domestic wells could be drilled without interference to surface- or ground-water rights. Future development of large-diameter wells to produce supplies of water much greater than is required for the domestic needs of one family could significantly influence already established surface-water and ground-water rights. Reduction in stream flow by surface diversions high in the canyon could have an influence on both surface- and ground-water rights and might also influence the quality of both the surface water and the ground water.

REFERENCES

Burnham, R. C., 1950, The climates of Utah: unpublished Master's Thesis, University of Utah, Salt Lake City, Utah, 107 p.

Crittenden, M. D., Jr., 1963, Emendation of the Kelvin Formation and Morrison(?) Formation near Salt Lake City, Utah: U. S. Geol. Survey Prof. Paper 475-B, p. 95-97.

-----1964, General geology of Salt Lake County, in Utah Geological and Mineralogical Survey Bull. 69, Geology of Salt Lake County, 1964: 192 p.

Evans, R. W., Jr., An analysis of Salt Lake City's 1952 flood: unpublished Master's Thesis, University of Utah, Salt Lake City, Utah, 51 p.

Marine, I. W., and Price, Don, 1964, Geology and ground-water resources of the Jordan Valley, Utah: Utah Geological and Mineralogical Survey, Water Resources Bull. 7, p. 35.

Marsell, R. E., 1964, The Wasatch fault zone in Salt Lake County, Utah, in Utah Geological Society Guidebook to the Geology of Utah, no. 18, 1964: 62 p.

Nelson, ElRoy, 1956, Utah's economic patterns: University of Utah Press, Salt Lake City, Utah, p. 8.

Trewartha, Glenn T., 1937, An introduction to weather and climate: McGraw-Hill Book Co., Inc., 1st Edition; New York and London, p. 225.

U. S. Public Health Service, 1962, Drinking water standards; Pub. no. 956: U. S. Govt. Printing Office, Washington, D. C., 61 p.